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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150787

DEVELOPMENT AND FABRICATION OF A CONCENTRATING SOLAR COLLECTOR SUBSYSTEM (Quarterly Reports)

Prepared from information submitted by

Northrup, Inc.
302 Nichols Drive
Hutchins, Texas 75141

Under Contract NAS8-32251 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy



(NASA-CR-150787) DEVELOPMENT AND
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Jan. 1978 - 30 Jun. 1978 (Northrup, Inc.,
Hutchins, Tex.) 67 p HC A04/MF A01 CSCL 10A G3/44

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U.S. Department of Energy



Solar Energy

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16. ABSTRACT This report covers work done from January 1, 1978 through June 30, 1978, including several types of testing and results and evaluation of the structural design of the Northrup "ML Series" Concentrating Solar Collector, Model NSC-01-0732 and the Attitude Control System. All cost information has been removed.					
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SUMMARY

During this quarter the new Northrup test facility was designed and a large portion was built. A prototype collector and framework were constructed. A new tracking box with a new motor was designed. The verification plan for the system was nearly completed. These items are more fully discussed in the following pages. Also included is a schedule for the remaining portion of this contract.

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TRACKING

A prototype collector and test frame with a tracking box similar to the MOD1 version were constructed within the Northrup facility. A tracking test was performed in which the prototype collector was tracked back and forth continuously. This type of drive mechanism appeared to be adequate for operating the prototype collector. However, it was felt that it might not be capable of driving a seven collector array since it had been designed for the smaller MOD1 collectors. Therefore, a new tracking box was designed with the following features:

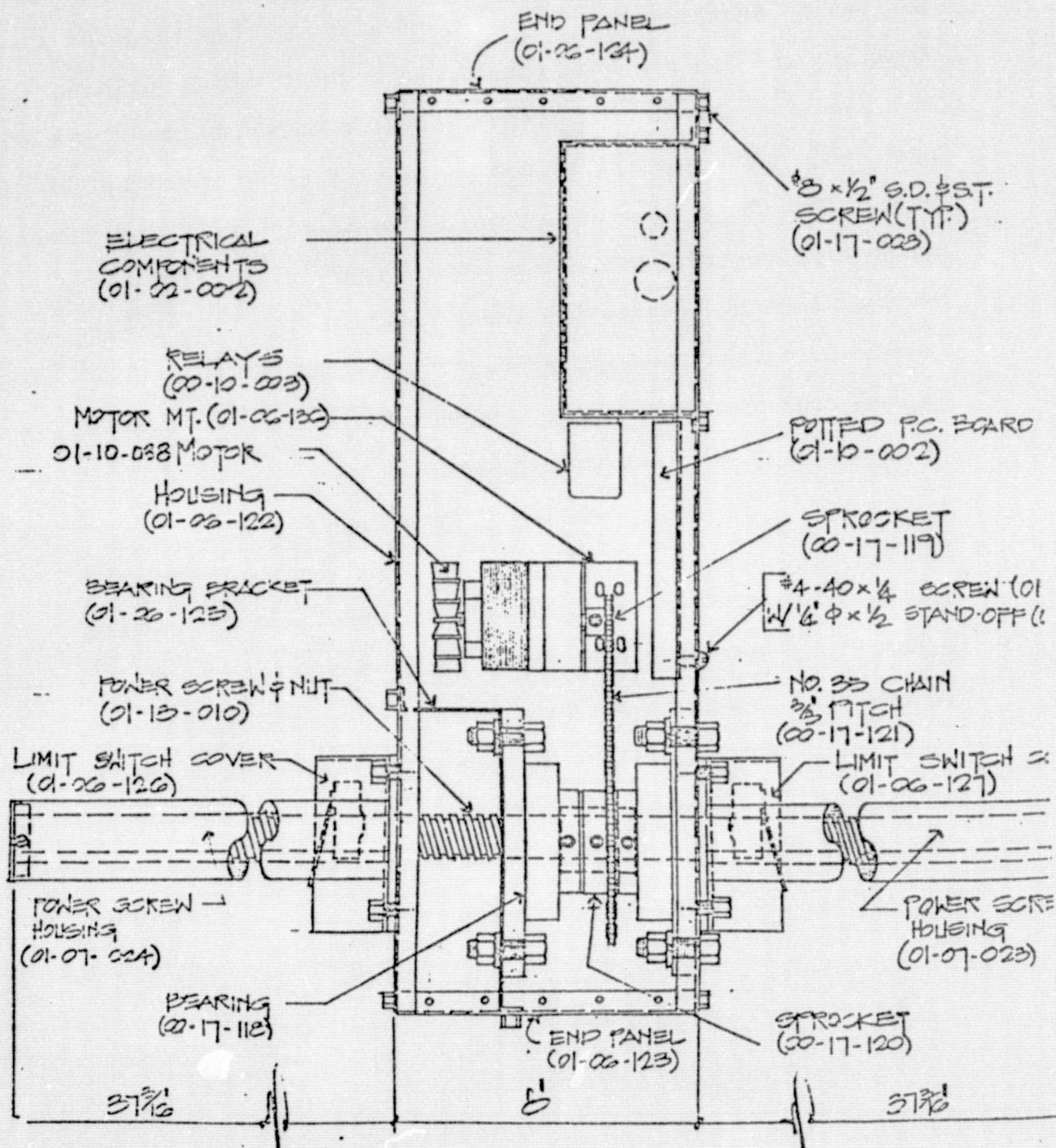
1. A chain-sprocket drive eliminates axial loading on the motor shaft. The sprockets are designed to provide a 1:5 gear ratio which will greatly reduce the torque required by the motor. The design concept is illustrated in drawing No. 01-03-069 included in this report.
2. A heavier duty motor than that required for the MOD1 tracking system is employed. It is rated at 30 inch pounds starting torque and 50 inch pounds breakdown torque. As a safety feature to prevent the motor from overheating a thermal cut-out switch is incorporated.
3. A delrin power nut is used to convert rotary motion into linear motion. The power nut which does not need lubrication is capable of operating with a working load of 1,000 pounds.

TEST FACILITY

A new test facility for the purpose of testing the multi-lens NASA collector has been designed and is currently being built behind the Northrup manufacturing building. Five thousand square feet of concrete has been poured and a sheet metal building has been installed. Collectors, testing devices, tanks and other necessary equipment are in the process of being moved out to the site. The fluid handling system shown in Figure A-1 is currently being constructed. The two separate tanks will allow quick thermal testing because the tanks can be held at different temperatures and used independently. So, when a collector is being tested with one tank at one temperature, the other tank will be heated to another test temperature.

VERIFICATION

The verification portion of contract NAS8-32251 is nearing completion. All test procedures have been written and forwarded to the Marshall Space Flight Center in Huntsville, Alabama. Final verification will be dependent on these test results. Additionally, various qualified independent professional engineers are now being sought to certify that the collector system meets national codes.



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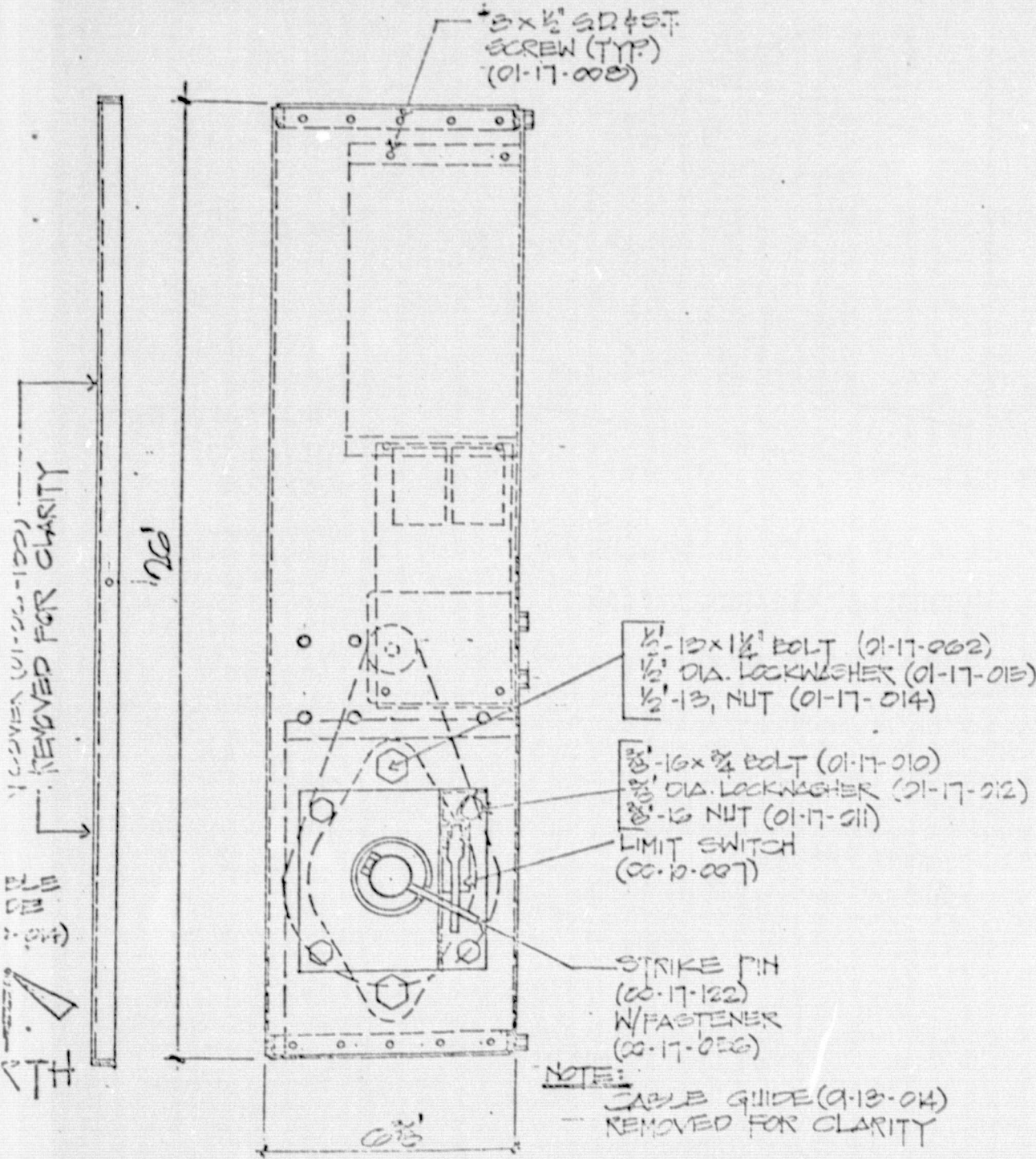
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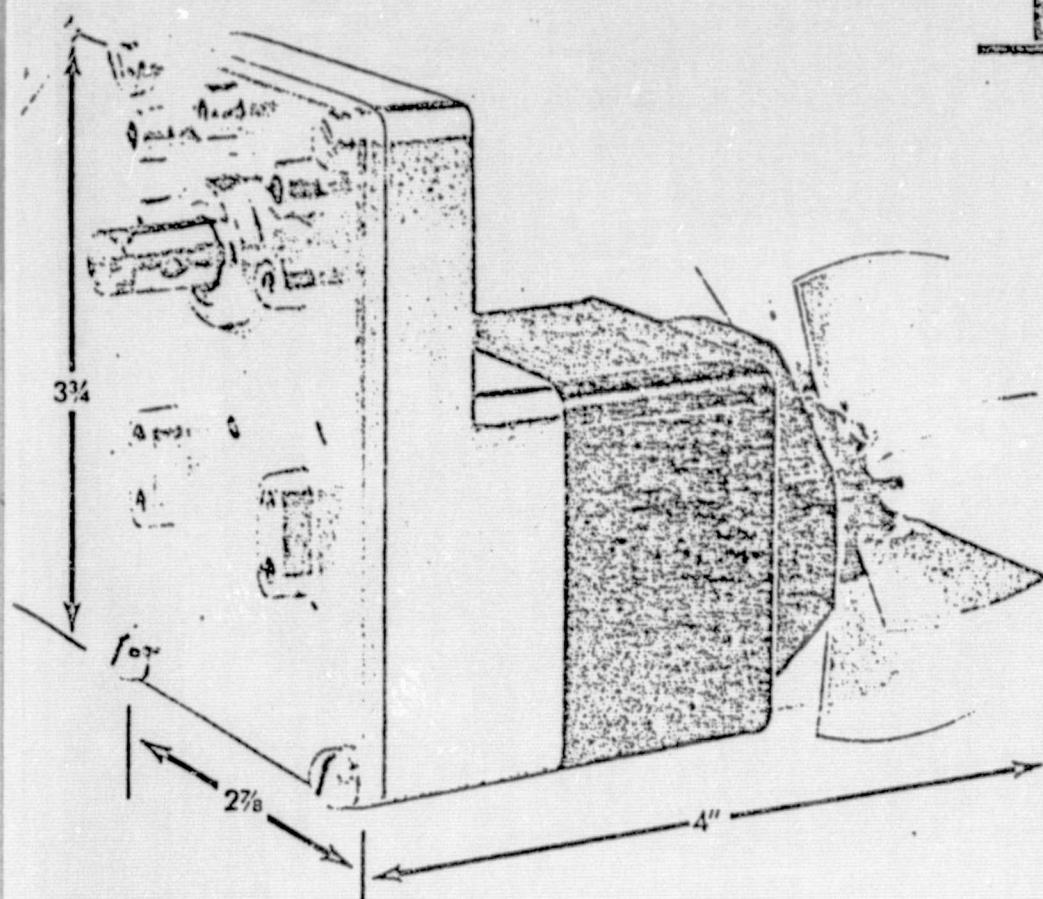
TRACKING CONTROL BOX CHOP ASSEMBLY

NOTEDHURUP

NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141



TRACKING CONTROL BOX



MODEL QFS SPLIT CAPACITOR REVERSIBLE GEARMOTOR

This model incorporates our new two pole split capacitor reversible motor and QF type gearcase.

Principal features of the QFS are starting torques comparable to many uni-directional motors of the same size and the proven reliability of Merkle-Korff's model QF gearcase—the ideal combination to provide you with a rugged, compact reversible gearmotor. Typical applications are document copying machines, vending machines and valve actuators.

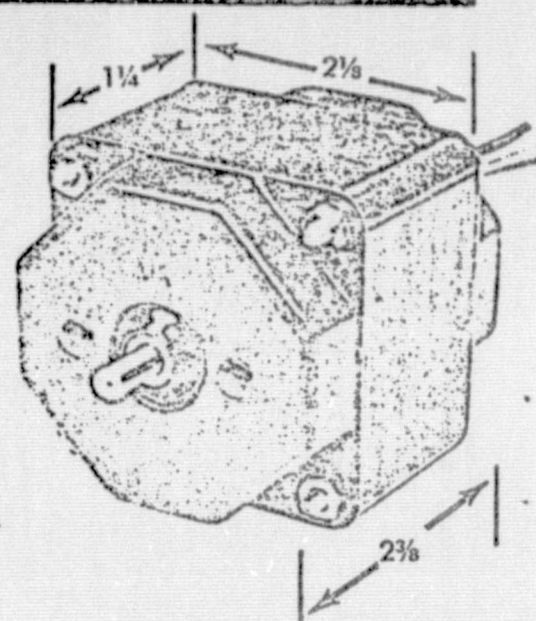
Some of the "extras" you can expect to find in the QFS, as in all other Merkle-Korff gearmotors, are precision gearing, sturdy shafts and bearings, positive alignment of the assembled parts and the shaft speed you want.

Options include special shaft machining, special gearing, brakes, thermal protection, lead terminals, fans, mounting provisions and anything else you might need to custom-fit the QFS into your application.

Call or write us with your specifications and application requirements. Let us show you what the QFS can do for you.



1776 Winthrop Drive, Des Plaines, IL 60018
Telephone 312-296-8300



HIGH STARTING TORQUE SPLIT CAPACITOR REVERSIBLE MOTORS

These compact, three wire, reversing motors are now available for OEM applications such as instrumentation, amusement devices, tape drives and many more.

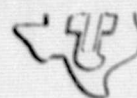
The motors come in stator sizes up to 1-1/4", with 3/16" diameter single or double extended rotor shafts. End bells are rust proofed and can be had ventilated or closed. Shaft bearings are self-aligning and permanently lubricated.

The nominal shaft speed of these motors is 3200 rpm, and a wide selection of starting torques are available based upon your duty cycle, coil windings, stator size and capacitor.

Thermal protectors, lead terminals and bi-directional fans are also available when your application requires them.

A call to our sales department will get prompt answers to your application, price and availability questions.

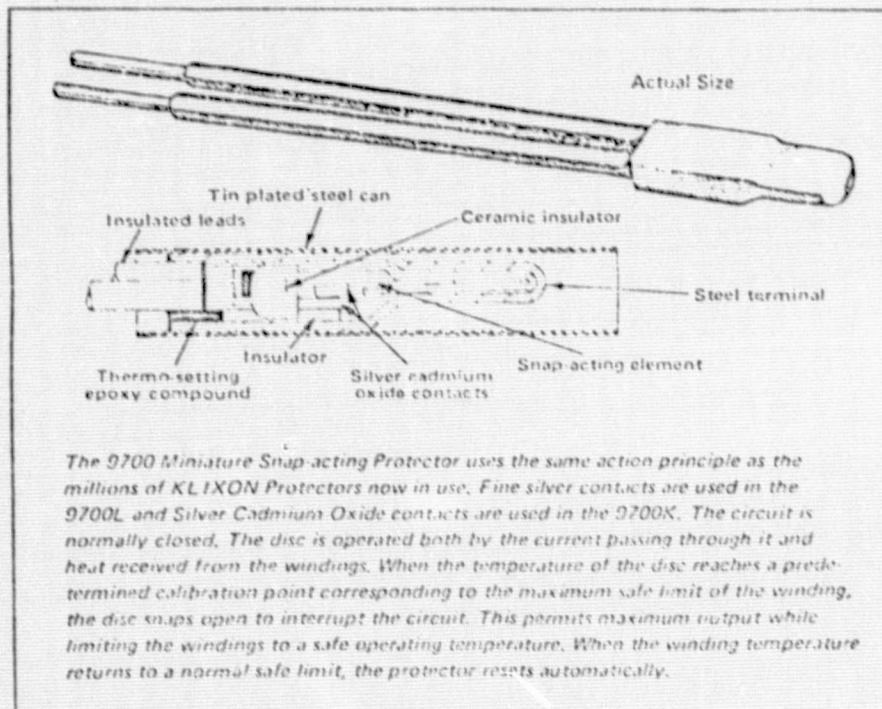
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KLIXON[®] MINIATURE PROTECTORS

9700 SERIES SNAP-ACTING

- Miniature Size — compact design assures ease of installation
- Precision Calibration — temperature calibrated and inspected in controlled ambients for dependable consistent performance
- Repeatability — maintains a high degree of uniformity of opening and closing temperatures throughout life
- Snap-action — positive make and break assured with proven KLIXON strip disc ... contact pressure at opening temperature eliminates nuisance trips due to vibration
- Sealed Steel Case — withstands impregnation and baking ... may be varnish dipped ... prevents changes in calibration during installation
- Maximum Safe Output — shuts down unit only when maximum allowable winding temperature is reached
- Fixed Differential — assures lower average winding temperature and prevents nuisance operation when restarting warm motors



*Mylar is a DuPont trademark

The KLIXON 9700 Protector is a field proven miniature protector developed to protect shaded pole and permanent split capacitor motors, fluorescent ballasts, solenoids, transformers and other electrical equipment against overheating.

In addition to being extremely small and lightweight, the unit is both temperature and current sensitive. Since the 9700 is sealed to withstand impregnation and baking, it can be mounted directly in the windings where it can best sense the true temperature of the electrical equipment. As a result, over-temperature protection is assured.

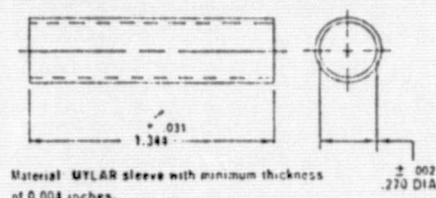
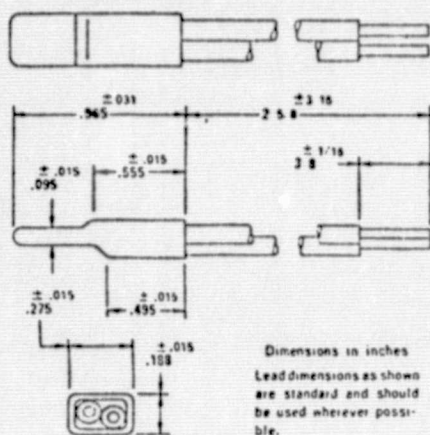
Since the case is not electrically insulated, the protector is furnished with a durable Mylar* insulating sleeve. Shrinkable and non-shrinkable sleeves are available.

DIFFERENTIAL

The 9700 has a fixed differential. This results in a much lower average winding temperature than the opening temperature of the protector should a heavy overload cause prolonged cycling of the protector.

Differential ranges from 20°C in the lower opening temperature ratings to 50°C in the higher opening temperature ratings.

TEXAS INSTRUMENTS
INCORPORATED



LEADS

Two types of standard lead configurations are provided on 9700K miniature protectors, designated by the final two digits of the part number. All -11 leads are 2 5/8" long, stripped 3/8", with UL 90° C neoprene-insulated # 18AWG stranded and tinned wire. All -33 leads are 3 1/2" long, stripped 11/16", with UL 125° C vulkene-insulated # 18AWG stranded and tinned wire.

CONTACTS

Standard contact material of the 9700K Series is silver cadmium oxide. It is recommended for all new applications. Fine silver contacts for low-current applications also are available (the 9700L Series). For further information on low-current protection, consult factory.

Maximum contact rating			
Type	Amperes		
	24v-dc	115v-ac	230v-ac
9700L	12	12	9
9700K	18	18	12

ENGINEERING TEST SAMPLES

Engineering test samples are available for your particular applications. The information requested below will permit selection of sample ratings.

1. Nameplate data.
2. Maximum permissible winding temperature.
3. Minimum continuous current to produce this temperature.
4. Stalled rotor (or equivalent) current.
5. Protector location temperature.
6. Length of time required to heat the winding to maximum permissible temperature under stalled rotor (or equivalent) condition.

UL-CSA RECOGNITION

The 9700K type has been recognized by CSA under File # 0400-192 as complying with the Thermally Protected Fluorescent Lamp Ballast Specification 523A. UL recognition for Class P protected ballasts has been obtained under File # E34618 dated 1/16/68.

The 9700L and 9700K have recognition for use in motor applications under the following number:

UL Report file #E15962 dated 12/31/59 revised 4/18/66
CSA Report #LR11372-15C dated 1/6/61

Limited short circuit recognition 9700L and 9700K		
Volts	Amperes	Fuse
120	1000	40A
240	1000	30A
600	1000	20A

Group fusing short circuit recognition 9700L and 9700K		
Volts	Amperes	Fuse
240	5000	150A
600	2000	110A

Standard ratings and part numbers		
Nominal opening temperature °C tol. ± 5°C*	Low resistance bimetal disc**	High resistance bimetal disc***
75	9700K51-11	9700K55-11
90	9700K21-11	9700K25-11
95	9700K31-11	9700K35-11
100	9700K26-11	9700K30-11
105	9700K16-11	9700K20-11
110	9700K33-11	9700K40-11
120	9700K01-33	9700K05-33
130	9700K11-33	9700K15-33
135	9700K06-33	9700K10-33
140	9700K66-33	9700K70-33
145	9700K76-33	9700K80-33

*Also available ± 8° C opening temperature tolerance.

**Current through the 9700 disc has a derating effect. In applications where the protector acts primarily on temperature alone and it is desired to minimize the effect of current on protector operating temperature — use these low resistance types.

***For faster tripping time due to current through disc.

For further information write or call:
TEXAS INSTRUMENTS INCORPORATED
MOTOR CONTROLS MARKETING
ATTLEBORO, MASSACHUSETTS 02703
TELEPHONE (617) 222-2800

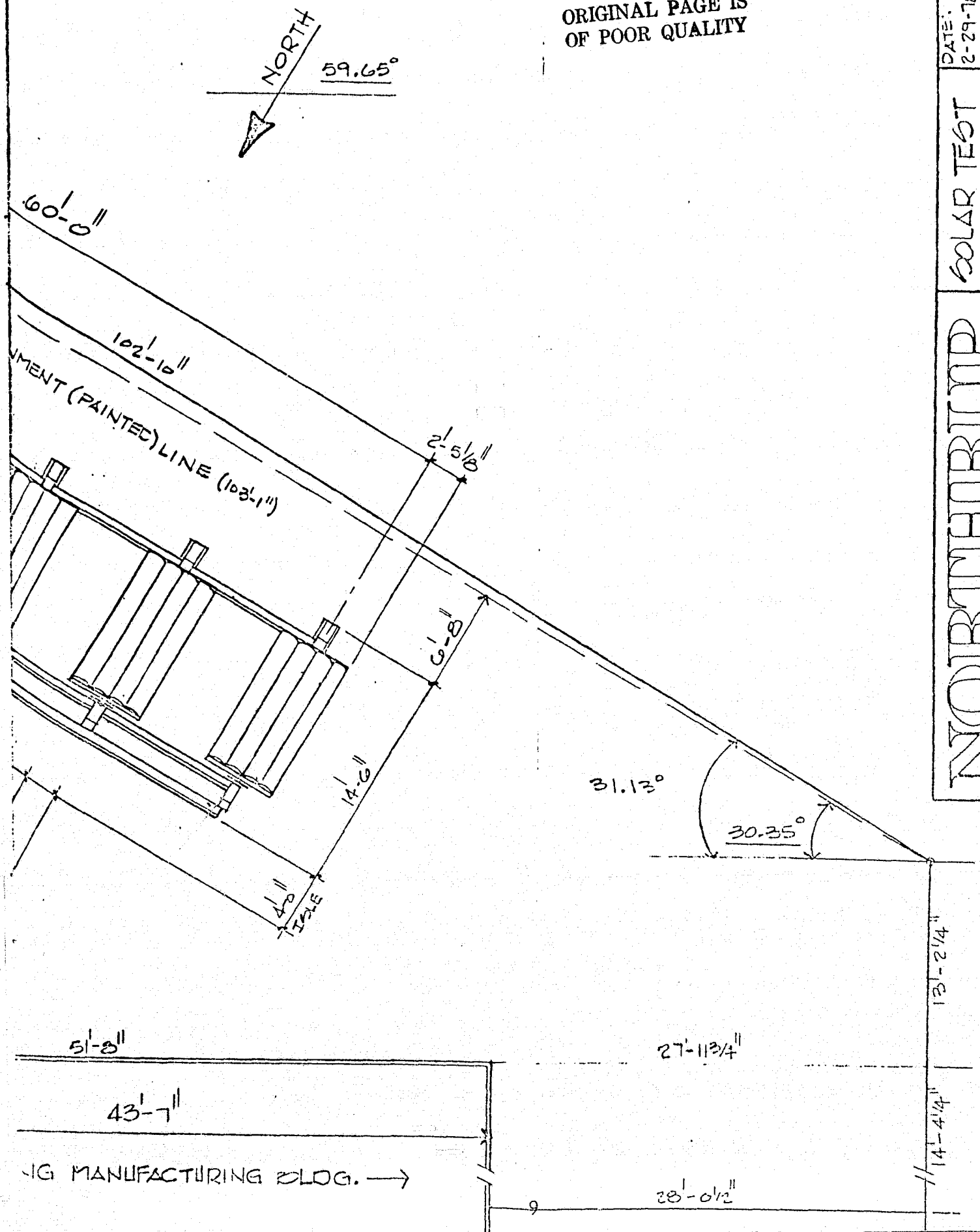
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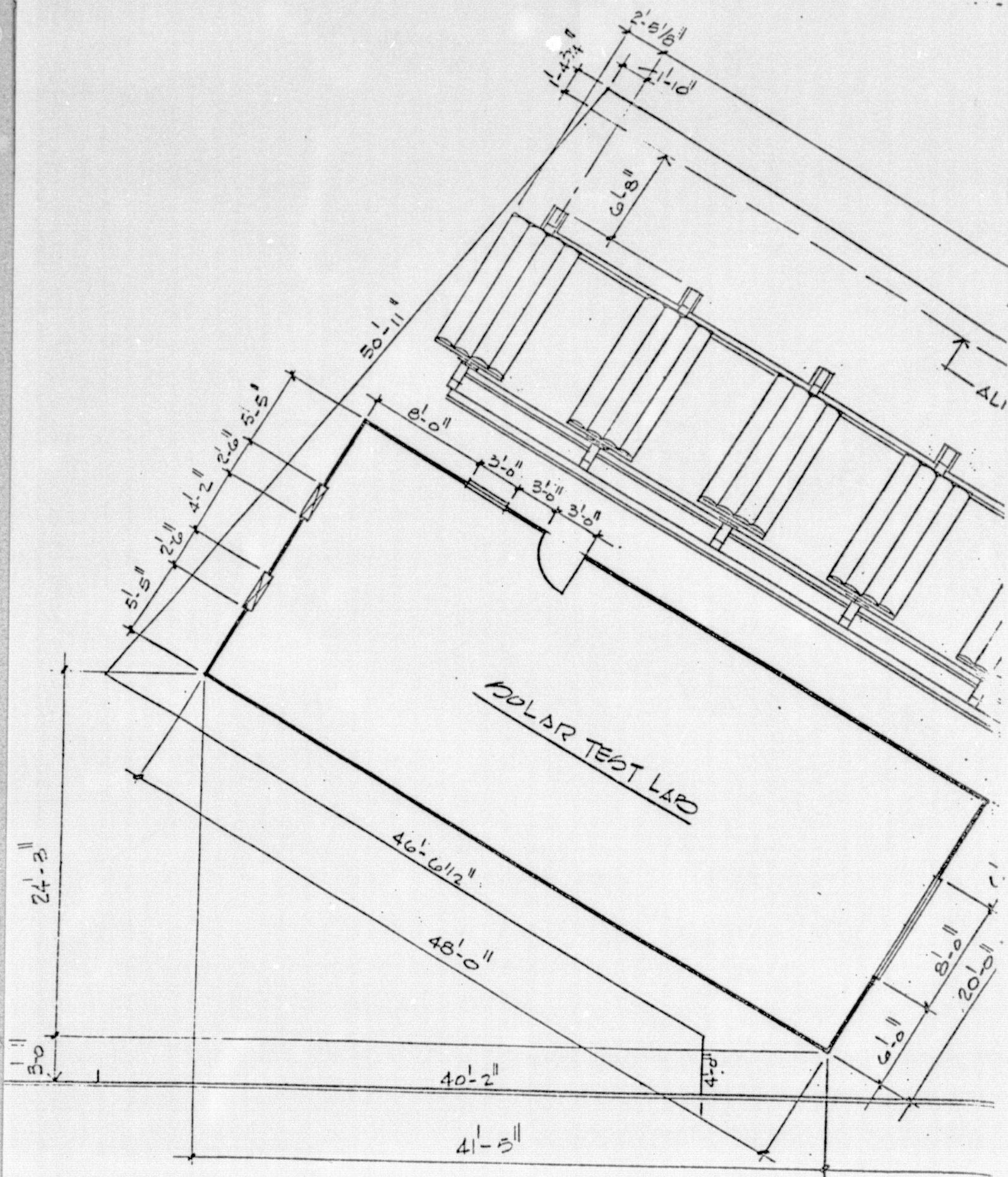
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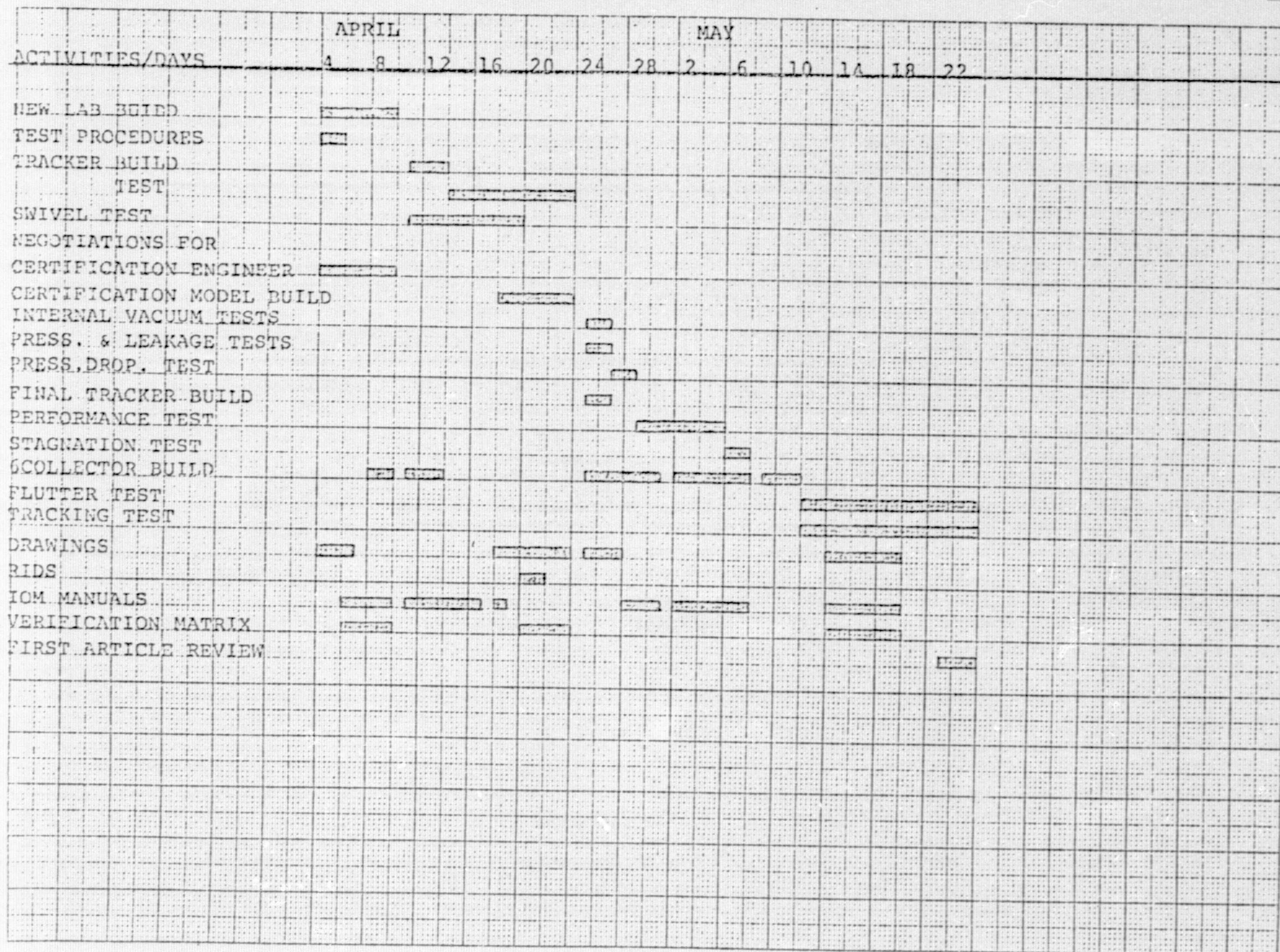
SOLAR TEST
FACILITY

NORTHROP
NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141



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SOLAR TEST LAB
FLUID SYSTEM

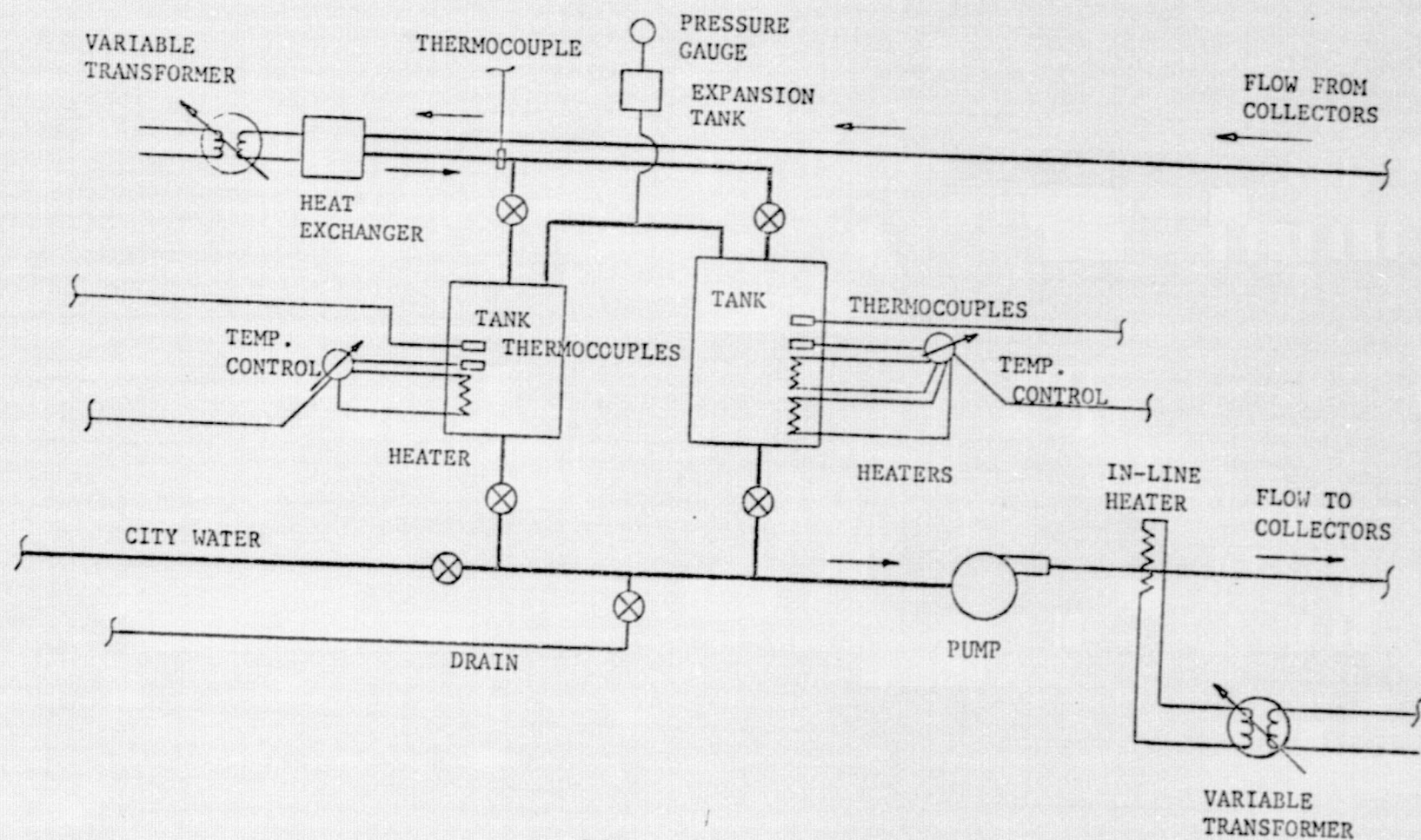


FIG. A-1

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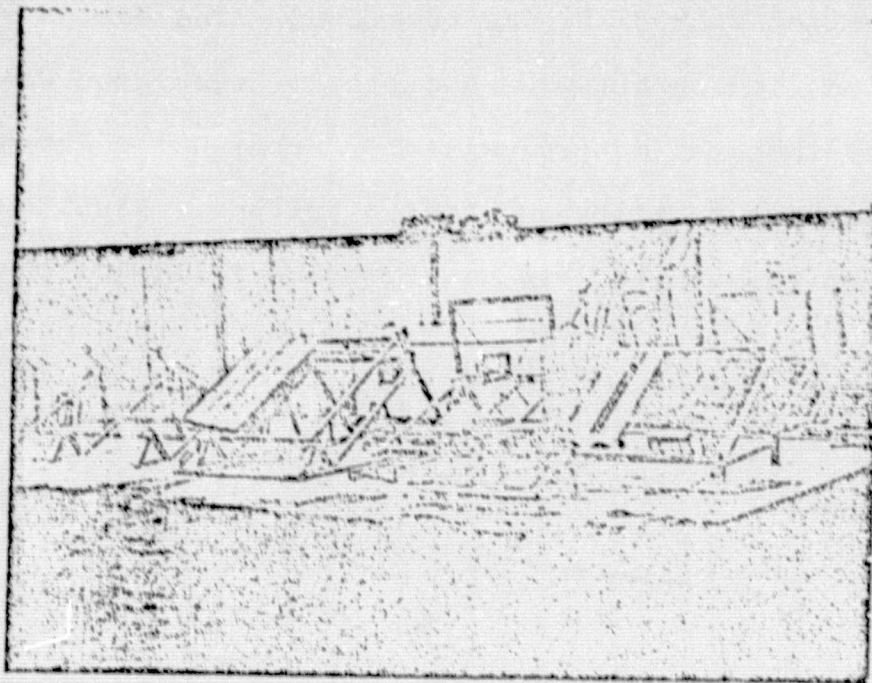
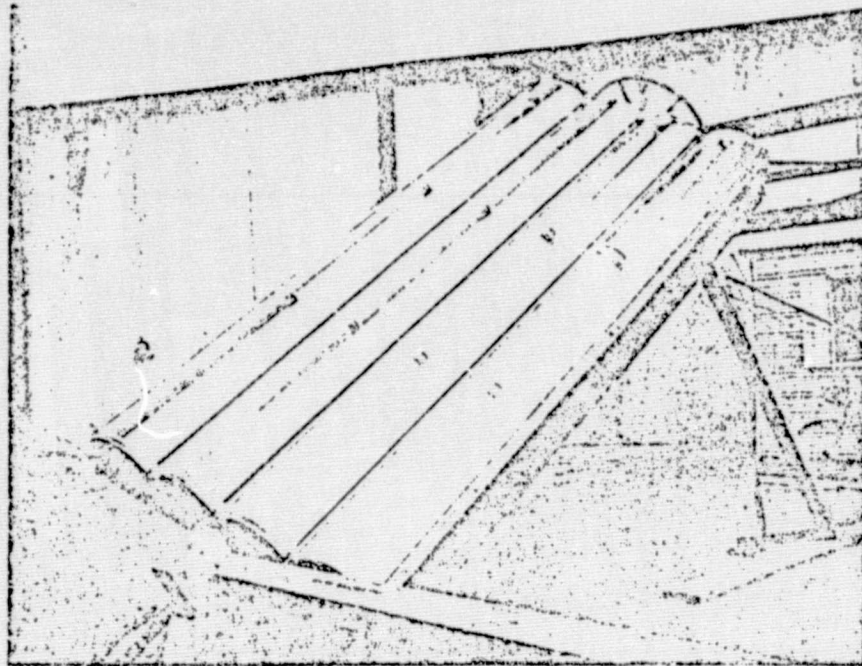


Fig. A-2 Solar Test Area

INTRODUCTION

In the course of this time period the collector system required by contract NAS8-32251 was completed. The design was finished, verified, and certified. A collector subsystem was thoroughly tested, then the entire collector array was constructed at the Northrup facility and tested further. Results of certification and testing are given in the following pages.



TEST COLLECTOR

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I. TESTS

THERMAL PERFORMANCE (EFFICIENCY)

INTRODUCTION

Efficiency curves for a 4-lens collector panel were determined for 0° and 12° incidence. The test procedure used was similar to ASHRAE Standard 93-77, although somewhat abbreviated.

EQUIPMENT

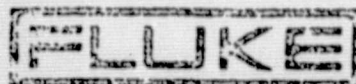
Two stainless steel sheathed Type T thermocouples to measure the collector inlet and outlet temperatures; a variable area flow meter to measure the flow rate through the collector; an Eppley standard pyrheliometer (with a clock drive) for direct insolation measurement; an Eppley pyranometer for total insolation measurement; an anemometer for wind velocity measurement; a Type 2240-A Fluke Datalogger to record instantaneous signals from the thermocouples, pyrheliometer, pyranometer, and anemometer, a thermocouple housed in a well ventilated instrumentation shelter painted white on the outside to be used in measuring ambient temperature.

CALIBRATION PROCEDURE:

1. Before the beginning of the efficiency tests, the thermocouple used for the ambient temperature measurement was checked against an Erco precision mercury-in-glass thermometer. They were compared in ice water, and then in ambient air. In either case, the thermocouple agreed to within $\pm .5^{\circ}$ F of the thermometer.
2. Prior to the efficiency tests, two stainless steel sheathed thermocouples were tested by placing them and the Erco precision mercury-in-glass thermometer in silicone heat transfer

fluid that was heated to about 320°F . The fluid was allowed to cool to about 60°F during which time the responses of the three temperature measuring devices were periodically monitored. In all cases, the thermocouples agreed to within at least 0.2°F of each other and to 0.5°F of the thermometer which was occasionally checked.

3. The flow meter was calibrated by running water through it at about 1.7gpm which corresponds to the proposed test flow rate through one collector panel. The actual flow rate was determined by running the water through the flow meter into a weigh tank while timing it, afterwards adjusting the flow-meter scale correspondingly. The procedure was repeated until the flow rate was calibrated to better than $\pm 1.0\%$. 40 lbs. of water was used on the final calibration run.
4. The anemometer was calibrated by the manufacturer prior to procurement about two years ago. Since wind velocity is not a part of the efficiency calculation, and, because the readouts from this instrument have agreed with local weather services, no attempt will be made to calibrate it.
5. The Datalogger was calibrated by the manufacturer March 3, 1978. Between calibration dates, which occur every six months, the Datalogger should be accurate to within $\pm 1\%$.



FLUKE SOUTHWESTERN TECHNICAL CENTER

CERTIFICATE OF CALIBRATION

MODEL 2240A SERIAL NO. 510012 DATE 3-28-78

The Fluke Southwestern Technical Center does hereby certify the above listed instrument meets or exceeds all published specifications and has been calibrated using standards whose accuracies are traceable to the National Bureau of Standards within the limitations of the Bureau's Calibration services, or have been derived from accepted values of natural physical constants, or have been derived by the ratio type of self-calibration techniques.

Applicable NBS Test Report Numbers: DC Voltage — 207627
AC Voltage — 807675
Resistance — 207693



SERVICE MANAGER

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Flow Meter Calibration

Run 1 Flow Meter Reading = 1.68 GPM

Measured Flow	Amount	Time
	40 lb	169 sec

$$\text{Actual Flow} = \frac{(40 \text{ lb}) (60 \text{ sec/min})}{(8.34 \text{ lb/gal}) (169 \text{ sec})} = 1.70 \text{ GPM}$$

Run 2 Meter Scale Adjusted Before Run 2

Flow Meter Reading = 1.67 GPM

Measured Flow	Amount	Time
	40 lb	172 sec

$$\text{Actual Flow} = \frac{(40 \text{ lb}) (60 \text{ sec/min})}{(8.34 \text{ lb/gal}) (169 \text{ sec})} = 1.673 \text{ GPM}$$

LIST OF SYMBOLS

- A - collector aperture area
- C - specific heat of the transfer fluid
- I_d - direct normal insolation
- I_t - total insolation
- $\dot{m}$ - mass flow rate of the transfer fluid
- η - collector efficiency %
- T_a - ambient temperature
- T_i - collector inlet temperature
- T_o - collector outlet temperature

TEST PROCEDURE THERMAL EFFICIENCY

- 1 The collector tilt angle was adjusted so that the lenses were approximately normal to the sun during the hours of data accumulation which were two hours before solar noon through two hours afterwards.
2. The water-flow rate through the collector panel was set at about 1.7gpm and recorded. During the progress of the test, the flow meter was checked every five minutes to ensure that the volume rate of flow did not change.
3. The pyranometer (total insolation measurement) was placed on a tracking mount that maintained near normal incidence to the sun. The pyrliometer (direct insolation measurement) was mounted on a clock drive which was aligned to the sun during the test. Each instrument as well as the collector aperture was wiped clean before the tests on each day.
4. Four different values of inlet fluid temperature were used to obtain the values of $(T_o - T_i)/I_d$, which is the abscissa value in the efficiency plot. Fifteen "data points" were used in the determination of the normal incidence efficiency curve. A data point encompassed a five-minute time span in which the total and direct insolation, the collector inlet and outlet temperatures, and wind velocity were recorded at one-minute intervals. The efficiency data point was then calculated as:

$$\eta = \frac{\sum_{n=1}^5 C(T_o - T_i)}{\sum_{n=1}^5 \frac{\dot{m}}{(A I_d)_n}}$$

which is essentially a numerical integration over the five-minute time span. The collector was allowed to stabilize before each test. During the five-minute intervals, the inlet temperature did not change by more than 0.6°F and the average wind velocity was lower than 10mph for all tests. The instantaneous efficiency curve was obtained using the technique of a linear least-squares fit.

5. In order to determine the efficiency at 12° incidence, another efficiency value was determined in general accordance with the methods previously described. The collector panel was oriented so that the average incident angle between it and the solar radiation for the test was 12 degrees.

RESULTS

The individual data points from the normal incidence test are shown plotted on the first of the two efficiency graphs that follow. Note that there is very little deviation of the points from the fitted curve, indicating that test conditions had stabilized. The equation for efficiency

$$\eta = .80 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

which is based on direct insolation only, was derived through the use of a linear least-squares fit.

One of the performance requirements of this contract states that the collector efficiency on February 21 and August 21 be the same or better than that of a performance specification which is shown on the second graph. The collector orientation on these two dates corresponds to a seasonal tilt angle of 12 degrees. The efficiency curve for 12 degrees (based on insolation normal to the plane of the collector) is

$$\eta = .79 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

which is nearly the same as the performance at normal incidence. Calculation of the 12° efficiency is included later in this report. The two curves are shown on the second efficiency graph relative to the performance specification. It can be easily seen that the performance specification is exceeded.

The second performance requirement of this contract is stated below.

For Dallas Texas, the single solar collector will collect a minimum of 1144 BTU/Ft²/day of energy at an inlet fluid temperature of 190°F (water). The tilt angle at this performance basis will

be equal to the latitude angle, azimuth of 0 degrees, average ambient dry bulb 100°F, wind velocity zero, August 21 date, direct normal noon solar flux of 283* BTU/Hr Ft², longitude of 97° degrees and 32° latitude.

When used primarily for heating a single collector will provide 1242 BTU/Ft²/day at an inlet fluid temperature of 150°F (water). The tilt angle at this performance basis is equal to the latitude angle, azimuth of 0 degrees, average ambient 50°F, wind velocity zero, February 21 date, direct normal noon solar flux of 316* BTU/Hr-Ft², longitude of 97° and 32° degrees latitude.

For the two dates mentioned above, a seasonal incidence angle of 12° will be maintained throughout the day. Therefore, the equation

$$\eta = .79 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

is used in the calculation of the all day energy gain. The values of direct normal irradiation are taken from the 1972 ASHRAE Handbook of Fundamentals. The final calculations, based on eight hours of sun tracking, are tabulated in the following pages. In either case, the calculated energy gain is greater than the performance requirements.

In conclusion, the 4-lens concentrating collector was tested according to the previously described procedures. Test data and calculations are included in the following pages as verification. The test results indicate that this collector exceeds the performance requirements of Contract No. NAS8-32251.

*ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, NY, 1972.

Air-Conditioning Cooling Load

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Table 3 Solar Position and intensity; Solar Heat Gain Factors* for 32 Deg North Latitude

Date	Solar Time A.M.	Solar Position		Direct Normal Irradiation, Btu/sq ft	Solar Heat Gain Factors, Btu/sq ft										Solar Time P.M.
		Alt.	Azimuth		N	NE	E	SE	S	SW	W	NW	Hor.		
Jan 21	7	1.4	65.2	1	0	0	1	1	0	0	0	0	0	5	
	8	12.5	58.5	202	3	29	160	189	103	9	8	8	32	4	
	9	22.5	45.0	263	15	16	175	216	169	16	15	15	83	3	
	10	30.6	33.1	295	19	20	135	219	212	45	19	19	136	2	
	11	36.1	17.5	206	22	22	67	221	238	110	22	22	166	1	
	12	38.0	0.0	399	23	23	25	174	246	171	25	23	176	12	
Half Day Totals					75	91	525	974	834	262	75	75	523		
Feb 21	7	6.7	72.8	111	4	47	102	95	25	4	4	4	9	5	
	8	19.5	63.8	244	12	64	205	217	95	12	12	12	63	4	
	9	29.3	52.9	287	19	32	199	218	149	19	19	19	127	3	
	10	38.5	38.9	305	23	24	151	241	189	31	23	23	176	2	
	11	44.9	21.0	314	25	25	76	208	213	87	25	25	207	1	
	12	47.2	0.0	316	27	27	29	155	221	155	29	27	217	12	
Half Day Totals					57	277	749	1031	780	227	94	97	689		
Mar 21	7	12.7	81.9	184	9	105	176	142	15	9	9	9	31	5	
	8	25.1	73.0	263	17	107	227	209	62	17	17	17	99	4	
	9	36.8	62.1	289	23	64	210	227	107	23	23	23	163	3	
	10	47.3	47.5	304	27	59	158	215	144	29	27	27	211	2	
	11	55.0	26.8	310	30	31	82	179	168	58	30	30	242	1	
	12	59.0	0.0	312	31	31	33	122	176	122	33	31	252	12	
Half Day Totals					122	368	891	1054	594	191	123	122	872		
Apr 21	6	6.1	89.9	66	9	54	65	37	3	3	3	3	7	6	
	7	18.8	92.2	206	17	147	201	136	15	14	14	14	61	5	
	8	31.5	84.0	255	23	144	228	178	30	22	22	22	130	4	
	9	43.9	74.2	278	28	103	206	188	58	27	27	27	159	3	
	10	55.7	60.3	290	32	52	156	173	87	33	32	32	234	2	
	11	65.4	37.5	295	34	36	83	135	108	40	34	34	263	1	
	12	69.6	0.0	298	35	35	38	82	115	82	35	35	272	12	
Half Day Totals					159	595	965	896	359	174	150	149	822		
May 21	6	10.4	107.2	113	32	108	116	55	8	8	8	8	21	6	
	7	22.8	100.1	211	35	170	204	115	19	18	18	18	81	5	
	8	35.4	92.9	249	29	165	220	149	27	25	25	25	146	4	
	9	48.1	81.7	269	32	128	198	155	37	30	30	30	201	3	
	10	60.6	73.3	279	36	76	150	138	54	35	35	35	243	2	
	11	72.0	51.9	285	38	41	82	102	68	39	37	37	269	1	
	12	78.0	0.0	288	39	39	41	59	74	59	41	39	277	12	
Half Day Totals					217	697	953	747	248	181	172	171	1079		
June 21	6	12.2	110.2	153	44	120	127	55	10	10	10	10	28	6	
	7	21.3	103.4	240	46	176	201	108	19	19	19	19	83	5	
	8	36.9	95.8	261	36	171	214	135	29	26	26	26	131	4	
	9	49.6	89.4	263	31	136	193	139	35	32	32	32	203	3	
	10	62.2	75.7	277	38	86	146	122	45	36	36	36	244	2	
	11	71.2	60.0	278	40	46	81	88	56	40	38	38	238	1	
	12	81.5	0.0	280	40	41	42	52	60	52	42	41	276	12	
Half Day Totals					252	744	972	672	224	189	180	180	1019		
July 21	6	16.7	107.7	113	55	105	112	53	8	8	8	8	22	6	
	7	23.1	100.6	213	37	167	198	114	19	18	18	18	81	5	
	8	35.7	93.6	241	31	163	216	145	29	26	26	26	145	4	
	9	48.4	85.5	261	34	123	195	150	37	31	31	31	199	3	
	10	69.9	74.3	271	37	78	148	131	53	35	35	35	240	2	
	11	72.4	55.3	277	39	43	82	99	66	40	38	38	265	1	
	12	78.6	0.0	278	40	40	42	58	71	58	42	40	271	12	
Half Day Totals					247	741	964	724	245	181	176	175	1069		
Aug 21	6	6.5	100.5	53	9	50	55	24	3	3	3	3	7	6	
	7	19.1	92.8	169	18	149	189	127	16	15	15	15	61	5	
	8	31.8	84.7	229	25	131	219	170	30	23	23	23	127	4	
	9	44.3	75.0	261	39	104	209	180	50	29	29	29	185	3	
	10	56.1	61.3	275	35	55	152	167	84	34	33	33	229	2	
	11	66.0	38.4	281	36	33	83	131	104	41	36	36	256	1	
	12	70.3	0.0	283	37	37	40	80	111	89	49	37	265	12	
Half Day Totals					169	562	923	658	349	189	159	154	638		
Sep 21	7	12.7	81.9	184	10	95	153	153	19	9	9	9	33	5	
	8	25.1	73.0	219	18	163	215	199	60	18	18	18	96	4	
	9	36.8	62.1	272	21	54	202	218	105	24	21	21	158	3	
	10	47.3	47.5	287	29	32	154	298	141	30	29	29	201	2	
	11	55.0	26.8	294	31	32	81	174	164	59	31	31	234	1	
	12	59.0	0.0	299	32	32	34	129	171	120	34	32	244	12	
Half Day Totals					173	555	846	1054	575	194	123	127	844		
Oct 21	7	6.8	73.7	93	4	43	92	85	24	4	4	4	9	5	
	8	18.7	64.0	229	13	63	195	205	50	13	13	13	62	4	
	9	29.5	53.0	273	19	33	193	239	144	20	19	19	125	3	
	10	38.7	39.1	292	21	25	147	214	163	32	24	24	173	2	
	11	45.1	21.1	201	27	27	75	202	206	85	27	27	233	1	
	12	47.5	0.0	204	28	28	30	151	214	151	30	28	213	12	
Half Day Totals					150	205	718	1044	759	225	101	106	677		
Nov 21	7	11.5	85.4	1	0	0	1	1	0	0	0	0	0	5	
	8	12.7	59.6	196	9	29	156	183	109	9	9	9	32	4	
	9	22.6	48.1	262	15	17	172	241	165	16	15	15	87	3	
	10	30.8	33.2	283	20	20	134	244	209	45	20	20	135	2	
	11	36.2	17.6	319	22	22	67	218	234	109	22	22	165	1	
	12	38.0	0.0	399	23	23	25	171	243	171	25	23	175	12	
Half Day Totals					79	92	521	965	831	258	77	76	505		
Dec 21	6	10.3	83.6	176	7	18	135	166	98	7	7	7	22	4	
	7	19.8	43.6	257	13	14	162	208	171	15	13	13	72	3	
	8	27.6	31.2	287	18	19	127	246	217	52	18	18	119	2	
	9	32.7	16.4	289	20	20	63	243	243	116	20	20	148	1	
	12	34.6	0.0	294	21	21	23	177	252	177	21	21	158	12	
Half Day Totals					67	16	442	947	844	273	68	67	443		
					N	NE	E	SE	S	SW	W	NW	HOR.	+P.M.	

* Total solar heat gains for DS (1 in.) sheet glass. Based on a ground reflectance of 0.20 and values in Tables 1 and 2.

February 21 · ALL DAY ENERGY GAIN

$$n = .79 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

$$T_i = 150^{\circ}\text{F}$$

$$T_a = 50^{\circ}\text{F}$$

$$E_T \text{ must be larger than } 1242 \text{ BTU/Ft}^2/\text{Day}$$

Solar Time	8:00	9:00	10:00	11:00	12:00
I_{DN}	244	287	305	314	316
$\frac{I_n + I_{n+1}}{2}$		265.5	296	309.5	315
$\frac{T_i - T_a}{I}$		.377	.338	.322	.317
n		.602	.621	.629	.632

$$E_T = 2 \cos (12^{\circ}) \left[(.602) (265.5) + (.621) (296) + (.629) (309.5) + (.632) (315) \right]$$

$$= 1442.6 \text{ BTU/Ft}^2/\text{Day} \quad 1242 \text{ BTU/Ft}^2/\text{Day}$$

August 21

ALL DAY ENERGY GAIN

$$\eta_{120} = .79 - .4986 \frac{(T_i - T_a)}{I}$$

$$T_i = 190^{\circ}\text{F}$$

$$T_a = 100^{\circ}\text{F}$$

$$E_T \text{ must be larger than } 1144 \text{ BTU/Ft}^2/\text{Day}$$

Solar Time	8:00	9:00	10:00	11:00	12:00
I_{DN}	239	263	275	281	283
$\frac{In+In+1}{2}$	251	269	278	282	
$\frac{T_i-T_a}{I}$	.359	.335	.324	.319	
η	.611	.623	.628	.631	

$$E_T = 2 \cos (12^{\circ}) [(.611) (251) + (.623) (269) + (.628) (278) + (.631) (282)]$$

$$E_T = 1317.5 \text{ BTU/Ft}^2/\text{Day} > 1144 \text{ BTU/Ft}^2/\text{Day}$$

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Efficiency at 12° Incidence Angle Based on Direct Insolation
Normal to the Plane of the Collector

At 0° Incidence:

$$\eta = .80 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

At 12° Incidence:

$$\eta = .739 \text{ @ } \frac{T_i - T_a}{I} = .104$$

The intercept of the 12° incidence curve will be different than the 0° curve if the amount of incident energy on the absorbers has changed. However, the slope will remain the same since the convective and radiative area did not change.

$$-.4986 = \frac{\text{Intercept} - .739}{0 - .104}$$

$$\text{Intercept} = .79$$

$$\eta_{12^{\circ}} = .79 - .4986 \left(\frac{T_i - T_a}{I} \right)$$

This is virtually the same as the 0° incidence curve.

461510

TITLE A LENS CONC COLL "ML" MODEL HSC-01-0732

PERSONNEL: C. JACOB
D. SEWER

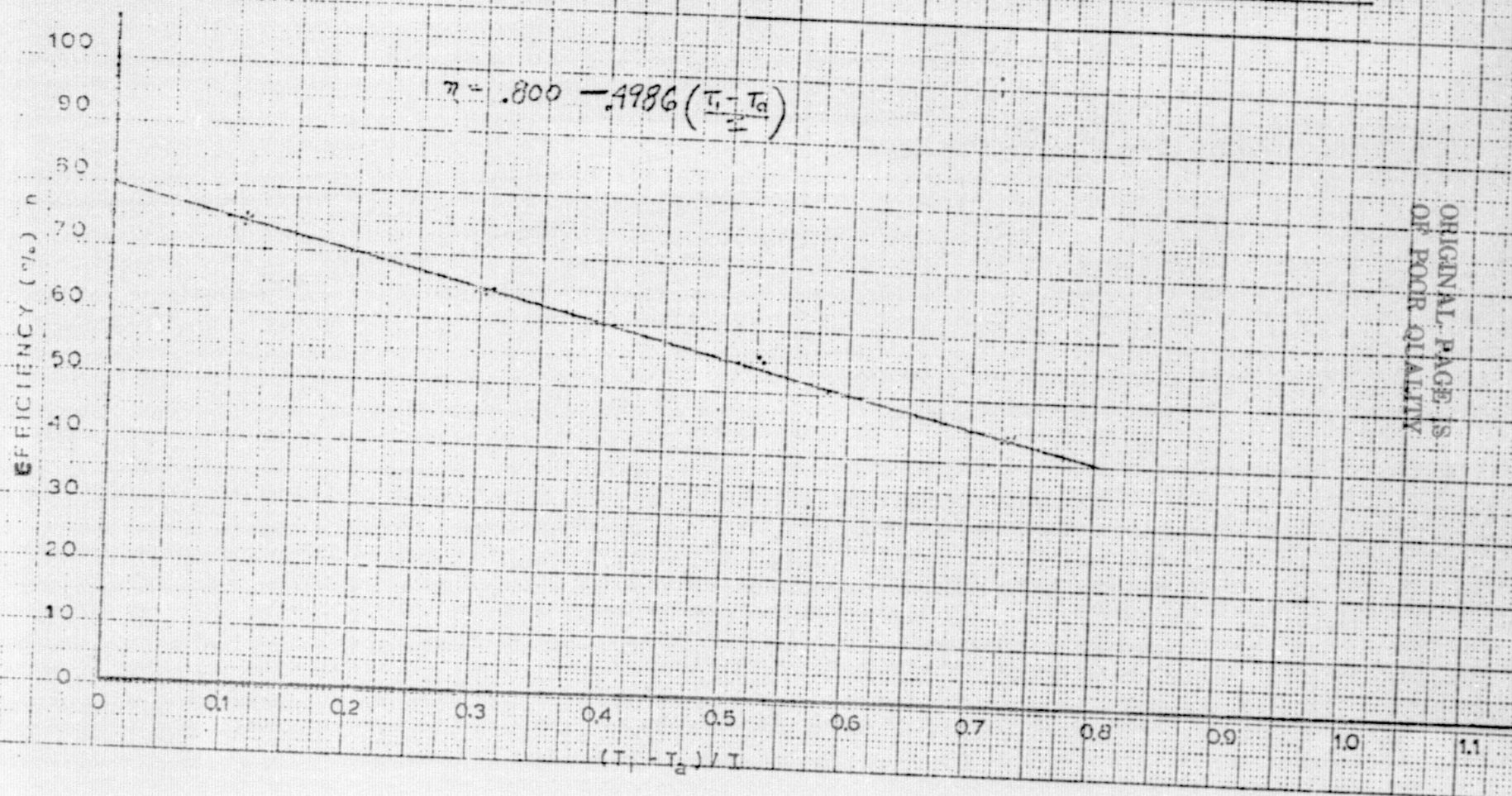
DATE: APRIL 25 & 26, 1978

TEST No: 182

CONDITIONS: CLEAR, 0° INCIDENCE ANGLE,
LIGHT WINDS, COLLECTOR TRACKING NORMALLY

$$\eta = \frac{M C_p (T_o - T_i)}{A_c I}$$

$$\eta = .800 - .4986 \left(\frac{T_i - T_a}{T_i} \right)$$

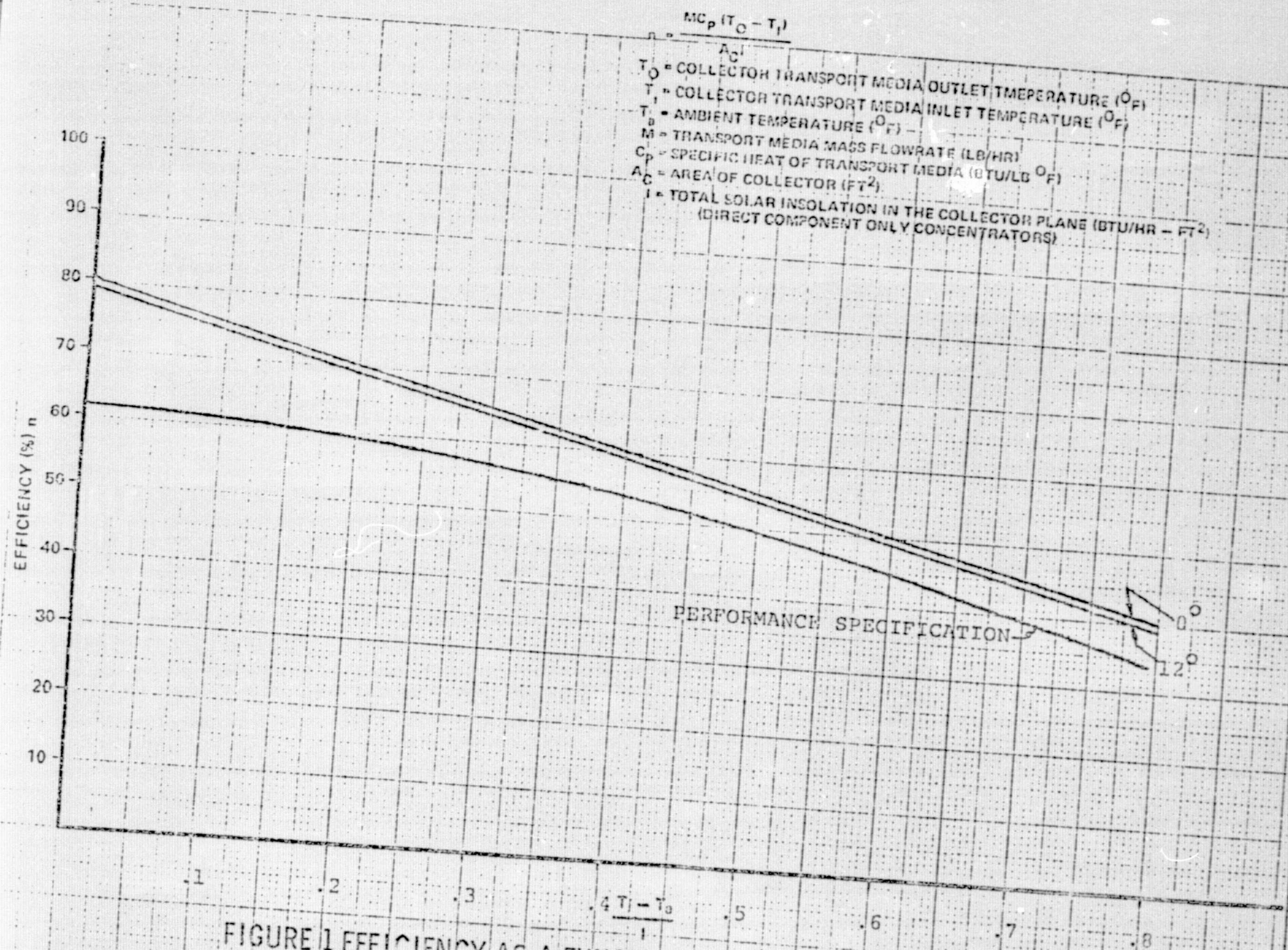


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SUBSYSTEM PERFORMANCE SPECIFICATION

APPENDIX A - TECHNICAL PERFORMANCE REQUIREMENTS

SPECIFICATION NO. _____
 REVISION _____
 DATE _____



- T_c = COLLECTOR TRANSPORT MEDIA OUTLET TEMPERATURE ($^{\circ}F$)
- T_a = COLLECTOR TRANSPORT MEDIA INLET TEMPERATURE ($^{\circ}F$)
- T_a = AMBIENT TEMPERATURE ($^{\circ}F$)
- M = TRANSPORT MEDIA MASS FLOWRATE (LB/HR)
- C_p = SPECIFIC HEAT OF TRANSPORT MEDIA (BTU/LB $^{\circ}F$)
- A_c = AREA OF COLLECTOR (FT²)
- I = TOTAL SOLAR INSOLATION IN THE COLLECTOR PLANE (BTU/HR - FT²) (DIRECT COMPONENT ONLY CONCENTRATORS)

FIGURE 1 EFFICIENCY AS A FUNCTION OF OPERATING CONDITIONS
 PERFORMANCE MUST BE ABOVE LINE

DATE: 4/25/78
WIND SPEED: 1.0 - 7.4
WIND DIRECTION: S.E.
CONDITIONS: VERY CLEAR DAY,
0° INCIDENCE ANGLE

$$EFF = \frac{m \cdot C_p (T_{out} - T_{in})}{A_c \cdot I''} \cdot \frac{\Delta T' (T_{in} - T_a)}{I''} = \frac{T_{in} - T_a}{T'}$$

@ 105°F $C_{p2} = 61.9 \text{ Btu/lb}^\circ\text{F}$
 @ 122°F $C_p = .977$

page of I

DATE: 4/26/78

WIND SPEED: 0-6 mph

WIND DIRECTION W - NW

CONDITIONS: MOSTLY CLEAR, SOME

LIGHT HAZE DURING 2nd "DATA PT"

0° INCIDENCE ANGLE

$$EFF = \frac{m C_p (T_{out} - T_{in})}{A_c I''} \cdot \frac{\Delta T'}{I''} = \frac{(T_{in} - T_a)}{I''}$$

TIME	T _a	T _{in}	T _{out}	WIND VEL.	FLOW	I	Σ I ΔT	m	I*	ΔT	Σ I I*	EFF	ΔT/I	AV. ΔT/I
13:14	71.0	211.1	218.0	2.2	1.72	313.1		823.6	252.3	6.9			.5542	
13:15	71.8	211.1	217.9	1.4	1.72	319.5		823.6	254.3	6.3			.5478	
13:16	72.2	211.2	218.2	5.3	1.72	319.3		823.6	255.0	7.0			.5451	
13:17	71.0	211.1	213.2	4.6	1.72	319.5		823.6	253.3	7.1			.5531	
13:18	72.2	211.2	213.3	2.5	1.72	319.2	269116	823.6	250.6	7.1	51439	.531	.5547	.551
13:19	71.5	211.2	218.2	2.7	1.72	315.2		823.6	246.4	7.0			.5670	
13:20	71.4	211.5	218.4	2.1	1.72	316.7		823.6	246.8	6.9			.5677	
13:21	73.0	211.7	218.2	0.0	1.72	299.1		823.6	228.3	6.5			.6075	
13:22	72.1	211.7	217.3	1.1	1.72	283.0		823.6	214.1	6.1			.6520	
13:23	72.3	211.8	217.6	0.3	1.72	286.1	26763	823.6	217.0	5.8	49518	.539	.6429	.607
13:24	72.4	212.0	217.7	2.0	1.72	305.3		823.6	237.5	5.7			.5373	
13:25	73.3	212.1	218.2	2.6	1.72	305.1		823.6	237.7	6.1			.5839	
13:26	71.9	212.1	213.6	0.2	1.72	306.5		823.6	239.8	6.5			.5347	
13:27	71.4	212.1	213.6	2.8	1.72	306.3		823.6	240.8	6.5			.5343	
13:28	71.2	212.1	213.7	1.4	1.72	309.9	26,016	823.6	244.9	6.6	51632	.504	.5753	.583
13:29	71.2	212.2	218.9	3.2	1.72	311.2		823.6	248.0	6.7			.5685	
13:30	72.1	212.4	219.1	4.1	1.72	312.0		823.6	251.9	6.7			.5570	
13:31	70.9	212.3	219.3	5.1	1.72	312.3		823.6	253.1	7.0			.5537	
13:32	71.7	212.3	219.4	5.2	1.72	312.1		823.6	252.6	7.1			.5566	
13:33	71.4	212.3	219.3	4.8	1.72	314.6	28585	823.6	255.3	7.0	54242	.527	.5505	.558

13:18-13:23 WAS NOT USED IN THE EFFICIENCY CALCULATION
BECAUSE THE INSULATION RATE CHANGED SIGNIFICANTLY
DURING THIS PERIOD.

$G_{215T} = 59.7 \text{ kg}$

1957	7	420/0
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COLLECTOR APERTURE: 43.0 42

DATE: 4/26/78

WIND SPEED: 0-5.3 mph

WIND DIRECTION: W-SW

CONDITIONS: CLEAR, 0° INCIDENCE
ANGLE

$$EFF = \frac{m \cdot C_p (T_{out} - T_{in})}{A_c \cdot I''} ; \frac{\Delta T'}{I''} = \frac{(T_{in} - T_a)}{I''}$$

[illegible]

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TITLE: EFFICIENCY @ 12° INCIDENCE P.W.E DATE: 4/27/78

4 LENS CONC. COLL. "ML" MODEL HSC-31-732. WIND SPEED: 1.2 - 7.1 mph

PERSONNEL: C. JAMES, D. SEITER

WIND DIRECTION: W-NW

TEST No: 53

CONDITIONS: CLEAR, 12° INCIDENCE

COLLECTOR APERTURE: 43.0 A²

ANGLE.

$$EFF = \frac{m \cdot C_p (T_{out} - T_{in})}{A_c \cdot I''} ; \frac{\Delta T'}{I''} = \frac{(T_{in} - T_a)}{I''}$$

$$\eta = \Sigma m C \Delta T / \Sigma A I^{1/4} [\cos(12^\circ)]$$

[illegible]

STAGNATION - DEFOCUSING TEST

May 9, 1978

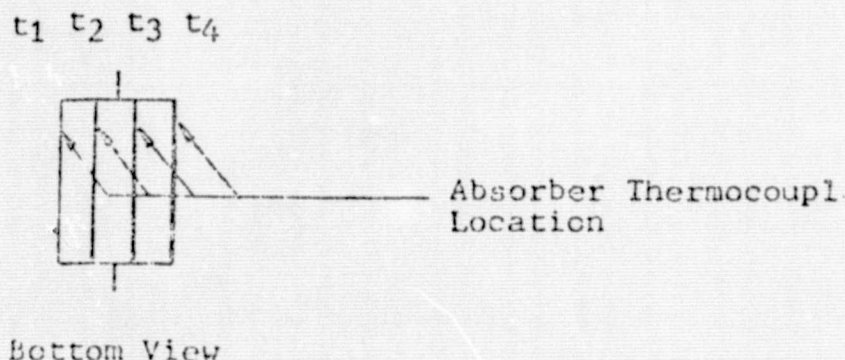
INTRODUCTION

The purpose of this test is to determine the maximum absorber and swivel temperatures during a stagnation-defocusing period corresponding to a power failure. The absorber temperature must not rise above 550° F or the black chrome coating may be permanently damaged. The inlet or outlet temperature must not rise above 350° F or the swivel O-ring may be damaged.

PROCEDURE

A 4-lens concentrating collector panel was allowed to come to steady state operating conditions: collector tracking and water flowing into the collector at approximately 1.7 gmp, with an inlet temperature above 200° F. After approximately 15 minutes of operating time, the water flow and tracking were simultaneously turned off. Absorber, inlet and outlet temperatures, direct insolation, wind velocity, and ambient temperature were recorded in one-minute intervals beginning five minutes before the point of fluid and tracking cut-off and extending to 45 minutes afterwards.

Positions of the absorber thermocouples are shown in the following diagram:



EQUIPMENT

See the "Thermal Performance (Efficiency), "

test for a description of the equipment. The "Stagnation Test" took place within about two weeks after the "Thermal Performance (Efficiency)" test so the equipment was not recalibrated.

The highest absorber temperature reached was less than 320 °F while the highest swivel temperature (outlet swivel) reached less than 270 °F. These are well below the recommended high limits of 550 °F for the absorbers and 350 °F for the swivels. Furthermore, this test caused absolutely no damage to the collector system. Therefore, there is no danger of the system overheating (when installed properly) due to a power failure.

Included with this report are plots of the absorber and outlet fluid temperatures as a function of time. All test data is documented. Note that the average direct insolation was greater than 280 BTU/Hr-Ft² and the average wind velocity was lower than 10 mph, which means that conditions were excellent for this test.

OUTLET FLUID TEMPERATURE VS. TIME

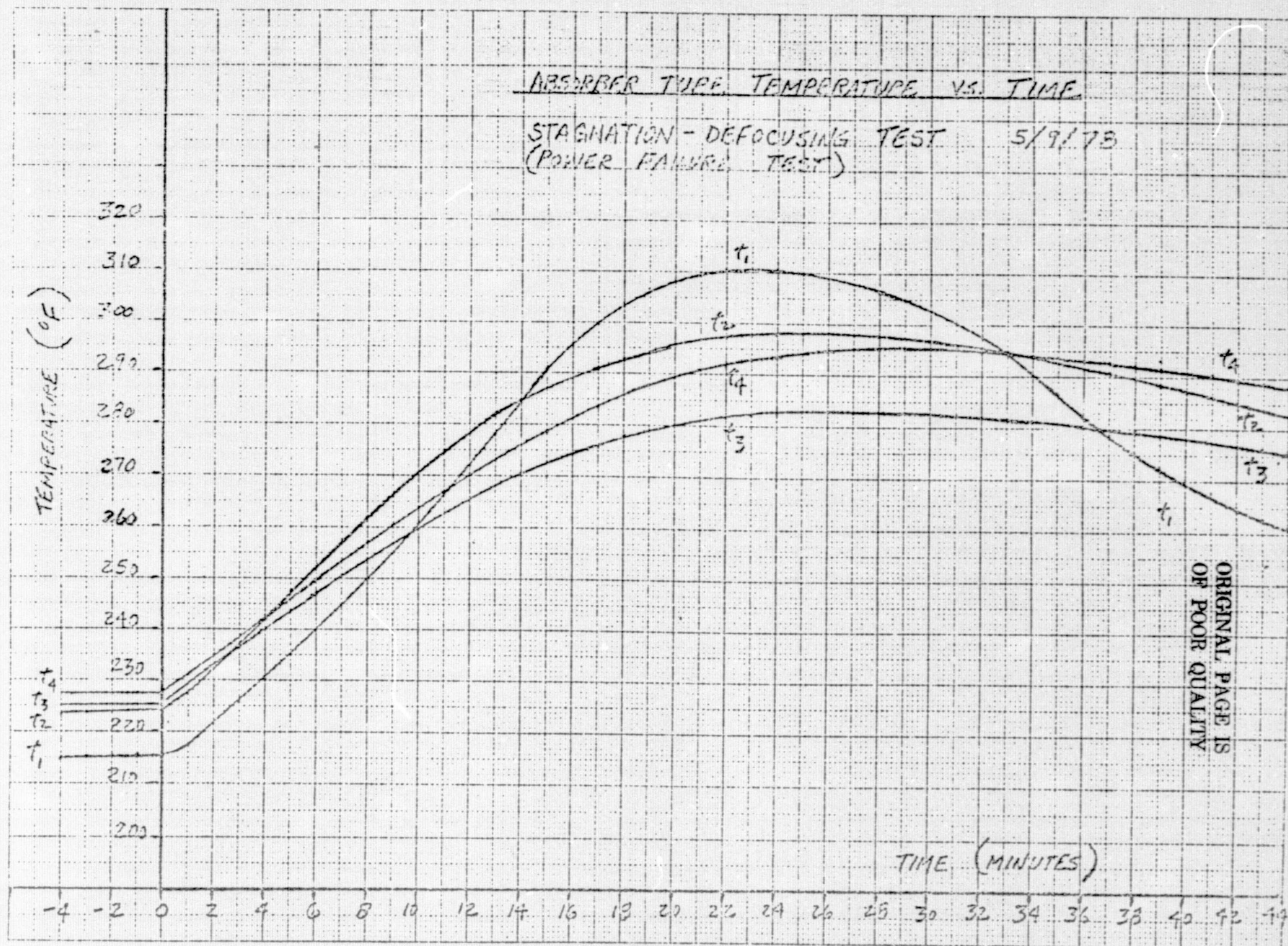
STAGNATION-DEFOCUSING TEST 5/9/73
(POWER FAILURE TEST)

TEMPERATURE (°F)

T_{out}

-4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44

320
310
300
290
280
270
260
250
240
230
220
210
200



TITLE: NASA CONCENTRATOR - 4-UNIT
STAGNATION

PERSONNEL: C. JACOPE / D. SEITER

TEST No: N0004

COLLECTOR APERTURE: -43.0 CM

DATE: 9 MAY 79

WIND SPEED: 1.9 MPH - 7.3 MPH

WIND DIRECTION: _____

CONDITIONS: CLEAR, CALM

t (absorber temp - °F)

$$EFF = \frac{m \cdot C_p (T_{out} - T_{in})}{A_c \cdot I''} ; \frac{\Delta T' (T_{in} - T_a)}{I''} = \frac{\Delta T'}{I''}$$

TIME	T _a	T _{in}	T _{out}	t ₁	FLOW	I _{DN}	t ₂	m	I''	ΔT	t ₃	EFF	ΔT'/I''	t ₄	W
1108	77.5	21.8	212.6	214.6	1.75	283.3	223.5		316.6		226.3			227.4	3.1
1109	76.1	21.9	218.7	215.2	1.75	284.1	223.9		317.1		226.2			227.2	4.1
1110	79.0	21.9	218.2	215.2	1.75	284.5	224.0		316.5		225.2			227.2	1.9
1111	77.8	21.2	218.2	215.4	1.75	283.8	224.3		316.3		225.2			227.3	4.1
1112	76.3	22.5	217.2	215.6	0	283.0	224.3		316.4		225.2			227.5	4.5
1113	78.7	20.2	207.1	217.4		282.9	227.4		315.7		225.4			227.5	4.1
1114	79.2	20.2	203.2	221.3		282.8	232.4		315.9		222.6			225.0	3.1
1115	77.7	20.6	207.4	225.2		283.8	237.6		317.2		226.2			231.0	3.1
1116	71.1	197.9	215.4	220.3	✓	284.5	242.2		317.1		240.1			242.1	3.1
1117	77.9	194.1	213.1	235.1		285.6	247.2		317.7		242.2			246.7	4.1
1118	79.5	173.1	224.1	240.1		284.1	252.6		317.6		247.1			250.1	3.1
1119	79.6	172.1	219.1	244.8		283.1	257.5		317.0		250.6			253.8	3.1
1120	77.6	170.9	221.3	250.7		283.2	262.1		317.1		252.9			257.2	3.1
1121	77.3	172.0	234.4	255.8		283.9	266.9		317.8		256.9			260.6	3.1
1122	77.7	171.7	237.0	261.9		282.7	270.6		317.5		257.2			262.2	5.1
1123	77.2	171.5	240.7	266.5		284.2	274.6		317.7		258.7			267.1	4.1
1124	77.9	174.7	242.7	272.0		284.6	278.3		317.8		260.6			271.3	5.1
1125	71.3	173.6	244.1	277.1		283.1	281.5		318.1		262.1			273.1	7.1
1126	81.5	172.2	247.1	282.0		283.7	284.5		317.8		272.6			276.1	1.1
1127	80.7	171.1	240.2	287.5		284.2	287.1		318.3		272.7			277.2	3.1
1128	81.6	170.2	243.7	292.9		282.7	289.1		315.7		274.6			281.4	7.1
1129	80.2	171.3	245.7	297.3		284.5	290.9		318.2		276.2			283.0	6.1
1130	80.4	170.7	251.7	299.5		284.6	297.2		318.9		277.5			285.2	3.1
1131	79.7	174.2	246.2	304.0		283.1	299.2		318.1		277.1			287.7	4.1
1132	77.7	173.1	247.7	309.1		284.2	302.4		318.3		277.1			291.2	4.1
1133	80.9	174.6	246.7	313.1		285.2	307.3		318.9		277.1			294.1	4.1
1134	79.7	170.1	248.7	317.1		283.7	311.1		318.3		277.1			297.1	5.1
1135	81.5	170.2	248.7	320.1		283.7	314.1		318.3		277.1			300.1	5.1
1136	81.1	171.3	248.7	323.1		283.5	317.1		317.2		277.1			303.1	5.1
1137	81.1	171.3	248.7	326.1		283.5	320.1		317.2		277.1			306.1	4.1
1138	81.1	171.3	248.7	329.1		283.5	323.1		317.2		277.1			309.1	4.1
1139	81.1	171.3	248.7	332.1		283.5	326.1		317.2		277.1			312.1	4.1
1140	81.1	171.3	248.7	335.1		283.5	329.1		317.2		277.1			315.1	4.1
1141	81.1	171.3	248.7	338.1		283.5	332.1		317.2		277.1			318.1	4.1
1142	81.1	171.3	248.7	341.1		283.5	335.1		317.2		277.1			321.1	4.1
1143	81.1	171.3	248.7	344.1		283.5	338.1		317.2		277.1			324.1	4.1
1144	81.1	171.3	248.7	347.1		283.5	341.1		317.2		277.1			327.1	4.1
1145	81.1	171.3	248.7	350.1		283.5	344.1		317.2		277.1			330.1	4.1
1146	81.1	171.3	248.7	353.1		283.5	347.1		317.2		277.1			333.1	4.1
1147	81.1	171.3	248.7	356.1		283.5	350.1		317.2		277.1			336.1	4.1
1148	81.1	171.3	248.7	359.1		283.5	353.1		317.2		277.1			339.1	4.1
1149	81.1	171.3	248.7	362.1		283.5	356.1		317.2		277.1			342.1	4.1
1150	81.1	171.3	248.7	365.1		283.5	359.1		317.2		277.1			345.1	4.1

* FOR CONCENTRATING COLLECTOR USE T ONLY

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TITLE: MASA CONCENTRATOR

4-UNIT - STAGNATION

PERSONNEL: C. JACOBS / D. SEITZ

TEST No.: N 000 f

COLLECTOR APERTURE: 43.041

DATE: 9 MAY 78

WIND SPEED:

WIND DIRECTION:

CONDITIONS: CLEAR

$$EFF = \frac{m \cdot C_p (T_{out} - T_{in})}{A_c \cdot I''} ; \frac{\Delta T'}{I''} = \frac{(T_{in} - T_a)}{I''}$$

[illegible]

* FOR CONCENTRATING COLLECTORY USE - INTERNAL ONLY

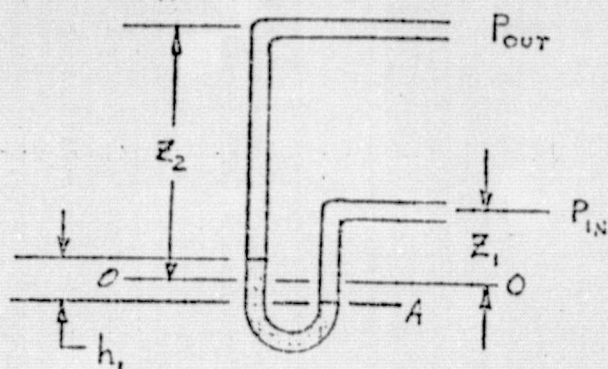
COLLECTOR PRESSURE DROP

The pressure drop between the inlet and outlet of a 4-lens collector panel (including both inlet and outlet swivel arrangement in the correct, bent tube, configuration) will be measured using a Meriam differential manometer. The flow rate through the collector panel will be at least 1.7gpm.

4- LENS COLLECTOR
W/ INLET & OUTLET
SWIVEL JOINT CONNECTORS

PRESSURE DROP TEST

5/20/78



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$$P_{IN} = P_A - \gamma_{H_2O} \left(z_1 + \frac{1}{2} h_1 \right)$$

$$P_{OUT} = P_A - \gamma_{Hg} h_1 - \gamma_{H_2O} \left(z_2 - \frac{1}{2} h_1 \right)$$

$$(1) \quad P_{IN} - P_{OUT} = h_1 (\gamma_{Hg} - \gamma_{H_2O}) + (z_2 - z_1) \gamma_{H_2O}$$

$$P_{IN} = P_{OUT} + D.L. + (z_2 - z_1) \gamma_{H_2O}$$

D.L. = DYNAMIC LOSS

$$(2) \quad D.L. = P_{IN} - P_{OUT} - (z_2 - z_1) \gamma_{H_2O}$$

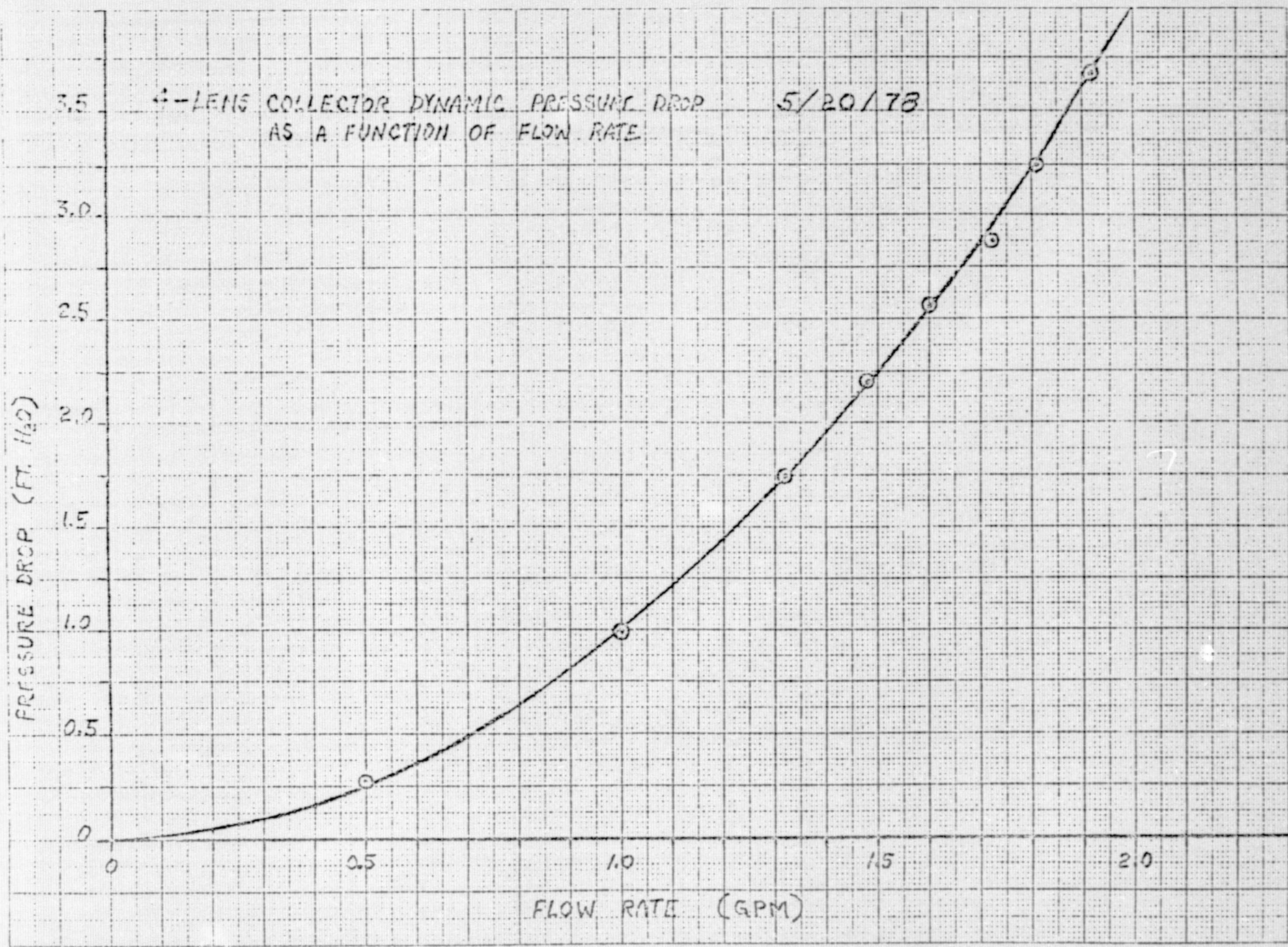
$$(1) \& (2) \Rightarrow D.L. = h_1 (\gamma_{Hg} - \gamma_{H_2O})$$

$$\gamma_{H_2O} = 62.4 \frac{\text{lb}}{\text{ft}^3}$$

$$\gamma_{Hg} = 845.3 \frac{\text{lb}}{\text{ft}^3}$$

FLOW RATE (GPM)	h_1 (INCHES)	D.L. (PSI)	D.L. (FT. H ₂ O)
0	0	0	0
0.5	.25	.113	.261
1.0	.95	.430	.993
1.32	1.65	.748	1.724
1.45	2.1	.951	2.194
1.6	2.45	1.11	2.560
1.72	2.75	1.246	2.873
1.81	3.1	1.404	3.239
1.92	3.5	1.586	3.657

44



INTERNAL VACUUM TEST

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INTRODUCTION

This test will ensure there is no danger that fluid handling components can be damaged due to an internal vacuum. The flattened absorber tubes, relief valves, and swivels will be individually tested. The copper pipe used in the manifold will not be tested since it is designed to withstand an internal vacuum, and since analysis indicates it can easily withstand the pressure created by an internal vacuum.

PROCEDURE

The absorber tubes, swivels, and relief valves will be tested separately by connecting the components in series with a 2-stage high-vacuum pump and a Stokes-McLeod mercury gauge with a scale range of 5000 to 0 microns. Each component will be subjected to an internal pressure of 1000 microns or less or will be shown to have vacuum relief protection. In either case, the component must not be damaged.

RESULTS

On May 29, 1978, the air vent was vacuum tested according to the above procedure. The air vent acted like a vacuum release valve by venting in air. This in itself should verify the system for vacuum relief protection since the system should not see an internal vacuum by virtue of the air vent.

In addition a swivel joint connector, pressure relief valve, and a flattened copper tube (ten feet long and with the same

cross sectional area as an absorber tube) were vacuum tested. They were subjected to absolutely no damage. Also, a cap was screwed onto the air vent to prevent its operation. It was then vacuum tested without damage.

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THERMAL CHANGES

5/20/78

During operating conditions a collector, swivel joints, lenses, housing, framework and the manifold (which were set up to handle one collector) were visually inspected to ensure there was no failure of the system due to excessive thermal expansion. The fluid inlet temperature was raised to 270⁰F for this test which is considered to be well above normal operating temperatures. During this test there were no failures nor any sign of a problem resulting from thermal changes.

PRESSURE TEST: NON-POTABLE FLUIDS

The portions of the system containing heat transfer fluid that would not necessarily be connected directly to the potable water supply are the manifold, absorber tubes, swivel connections, air valve, and pressure relief valve. The suggested working pressure for the system is 100 psi. The pressure relief valve is preset to open at 125 psi.

The aforementioned components, except the manifold are pressure tested before they go into operation. The test is performed by submersing the desired subsystem in water and filling it with nitrogen gas to the desired pressure level. If there is a leak, it will manifest itself in the appearance of bubbles. The pressure relief valve is tested up to its rated release pressure to ensure proper function. The other components are tested at 150 psi. None of these tests have resulted in leaks or damage to components when the subsystem was assembled correctly. Therefore, a working pressure of 100 psi should be acceptable.

Any connecting pipe from the collector array to and including a heat exchanger is not part of this contract and is considered the responsibility of the user.

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PRESSURE TEST

All the absorber tubes were pressure tested to 150 psig on April 7, 1978, according to the procedure described on the preceding page. The air vent and one of the swivel joint connectors were pressure tested to 150 psig on May 29, 1978 according to the previously described test procedure. In all of the above tests there were no failures of any kind. The pressure relief valve was also tested on May 29, 1978. This valve opened at 125 psi as specified by the manufacturer.

TRACKING TEST

Procedure

The entire collector array consisting of seven panels will be tested for alignment accuracy. The collector panels will be tracked without fluid flow during this test. All seven collector panels will be aligned to the sun by focusing the concentrated light from the lenses onto the absorbers. The panels will then be allowed to track the sun as they would in normal operation. The collector panels will be periodically checked visually for alignment accuracy.

Results

The array was allowed to track for eight days (6/22/78 through 6/29/78). During this period of time the collectors remained aligned to the sun during clear weather.

FLUTTERING TEST

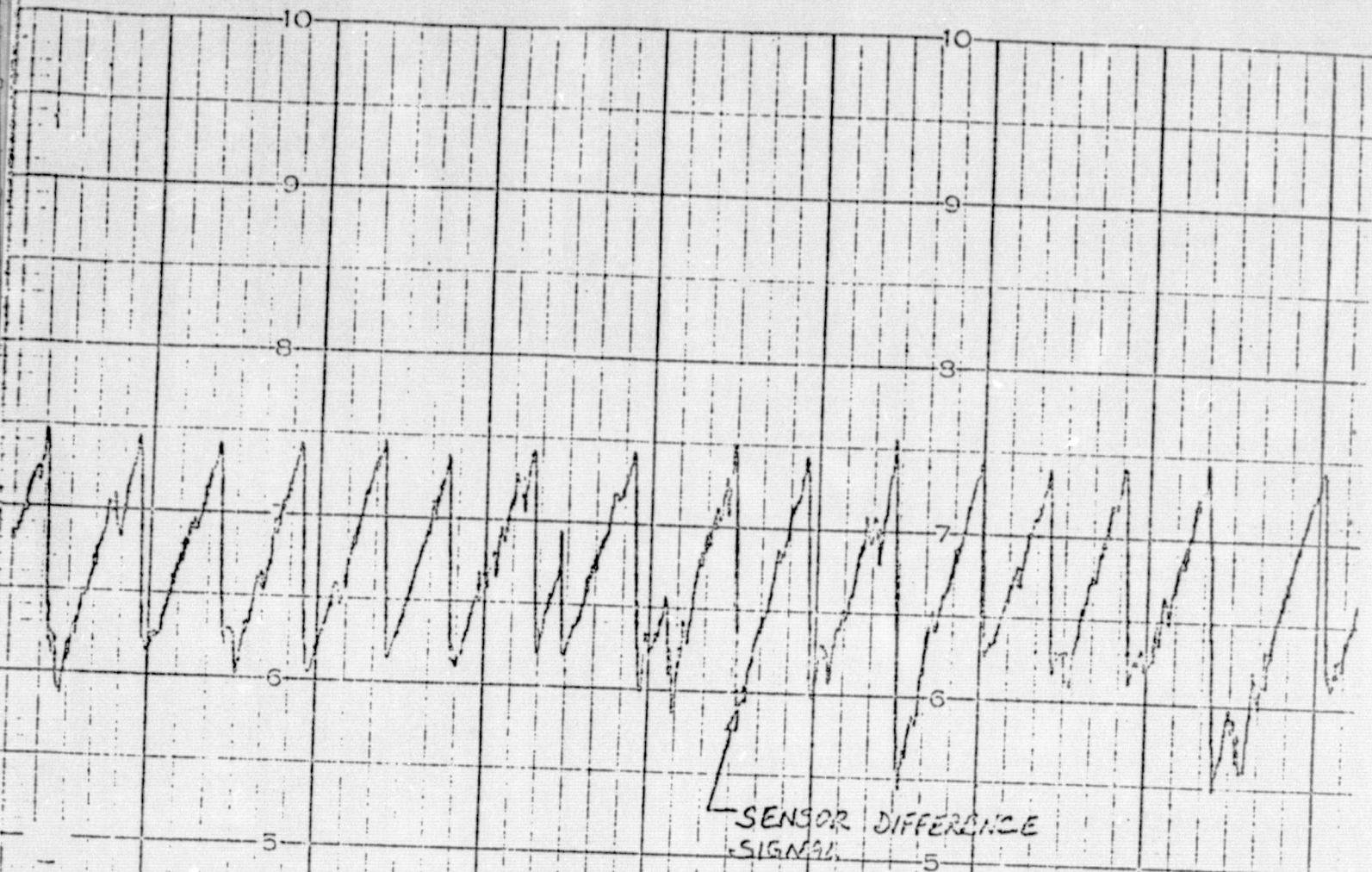
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Procedure

Wind flutter for the entire collector array was checked by inspection during eight days of tracking (6/22/78 through 6/29/78). Wind and temperature data were taken by our instrumentation. The voltage across the solar sensor was recorded by a strip-chart recorder. In addition, impulses from the electronic control board that indicate tracking direction were recorded.

Results

As evidenced by the strip-chart recordings, the wind did not interfere with tracking. That is, the time space between west tracking update periods remained reasonably constant throughout each test and there was never any evidence that wind had caused the collectors to track east. The strip chart recordings immediately follow.



5:00 PM 6/22/78

WIND 6-8 MPH

TEMP 99°F

4 LENS COLLECTOR

7 COLLECTOR ARRAY

← 60 SEC →

WEST TRACKING

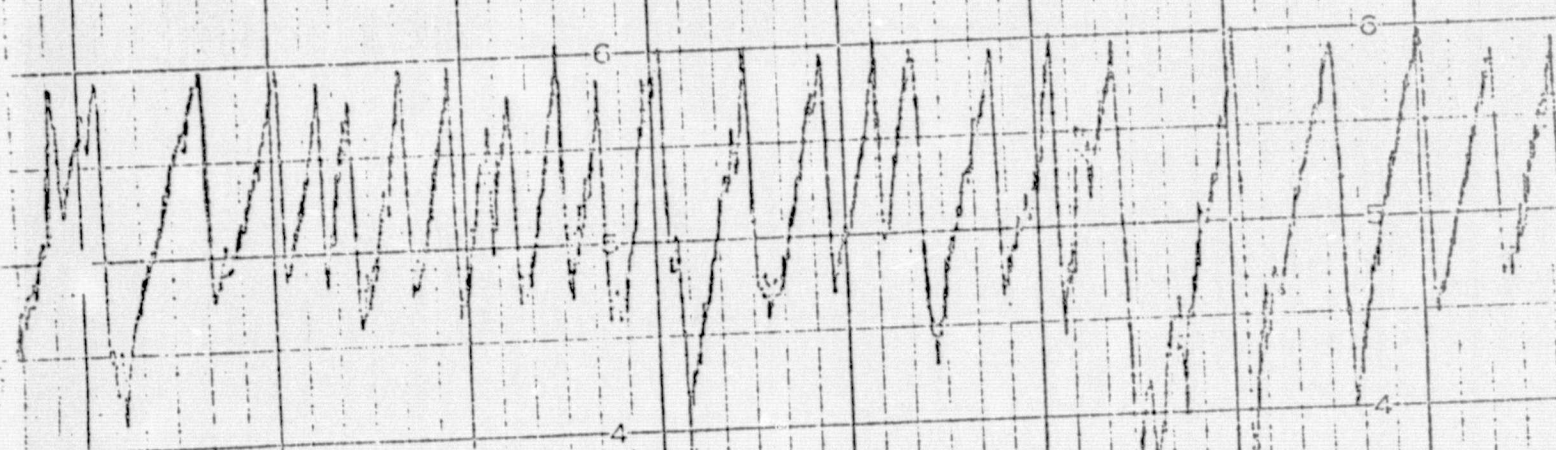
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11:45
6/23/78

WIND 5-7 MPH

A FEW LIGHT CLOUDS PRESENT

TEMP 96°F



4 LENS COLLECTOR
7 COLLECTOR ARRAY

SENSOR
DIFFERENCE
SIGNAL

← 60 SEC →



4:35 PM
6/26/78

LIGHT HAZE PRESENT

8-12 MPH
100°F

4 LENS COLLECTOR
7 COLLECTOR ARRAY

SENSOR DIFFERENCE
SIGNAL

60 sec

WEST TRACKING

ACCELERATED SWIVEL & FLEXIBLE JOINT LIFE TEST

PROCEDURE

The proposed swivel-flexible hose joint will be mounted on a test fixture that will simulate actual field operation. The hose end will be connected to a stationary tube while the swivel end will be connected to a tube that will rotate 180° in one direction, then will rotate back 180° to the original position. This complete cycle will take place every 69 seconds as opposed to an actual collector-swivel arrangement which would undergo a cycle once a day. During the accelerated test, approximately a 50% ethylene glycol-water solution will flow through the swivel. The fluid temperature will be varied so that its temperature will be about 160° F for a portion of each day and about 260° F for the remaining part of each day. It is hoped that the swivel-flexible hose joint will survive six (6) days of testing without leaking which corresponds to more than twenty (20) years of cycles in a real collector situation. There is ample reason to believe that this swivel will pass the test since a similar design has easily met this requirement.

RESULTS

The accelerated swivel-flexible joint life test was performed according to the above procedure. The test was started May 15, 1978, and allowed to run at 80 psig for a duration of six days.

The test was repeated at 100 psig beginning May 23, 1978, and run for a duration of six days. Once each day in both tests the pressure was reduced to zero psig to ensure that there would be no leaks at low pressure. For the second test the fluid temperature was maintained at approximately 200° F throughout.

In either test there was no leaking of the swivel joint. The flexible hose and the O-ring showed no signs of deterioration.

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II. CERTIFICATION

INTRODUCTION

This document constitutes the certification of the Northrup ML Series Collector, Model NSC-01-0732.

CERTIFICATION STATEMENT

The ML Series concentrating Collector complies with the following national codes where applicable:

National Standard Plumbing Code, National Association of Plumbing-Heating-Cooling Contractors 1971.

Frank A. [Signature]
Professional Engineer



National Electrical Code 1975

John A. Swage
Professional Engineer

Building Code ANSI A58.1-1972
Applied to the Dallas/Ft. Worth Region
For Installations less than 30 ft. above ground

Bijan Mohraz
Professional Engineer

I have reviewed the performance requirements, testing procedures, test facility, and data for the ML Series Concentrating Collector, Model NSC-01-732 under Contract No. NAS8-32251. I am able to certify that the collector satisfies those requirements.

T. J. Lawley
Professional Engineer

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3005 Hanover
Dallas, Texas 75225
May 28, 1978

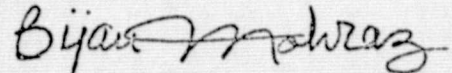
Mr. Carl L. Jacobs
Northrup, Incorporated
302 Nichols Drive
Hutchins, Texas 75141

Dear Mr. Jacobs:

As you requested in your letter of April 20, 1978, and in our discussion on May 2, 1978, at the Northrup plant, I have examined the structural design of the supporting system for the Northrup ML Series Collectors, Model NSC-01-0732. My observations and evaluation of this system are enclosed.

It was a pleasure to work on this project. Please let me know if you have questions or need additional information.

Sincerely,



Bijan Mohraz, Ph.D., P.E.

EVALUATION OF THE STRUCTURAL DESIGN OF THE
NORTHROP ML SERIES COLLECTORS
MODEL NSC-01-0732

Analysis of the Supporting System

Several analyses of the supporting system were carried out using the ACES (Analysis of Civil Engineering Structures) computer program. The supporting structure was idealized as a combination of frame and truss system since it is believed that the connections at the upper ends of the south brace assembly and the north column assembly are not completely rigid.

Four separate solutions were obtained for the following load conditions:

- a. Dead load The analysis for this loading condition was carried out using the loads provided by Northrup which are based on the actual weights of the components.
- b. Live load The analysis for this loading condition was carried out based on a live load of 16 pounds per square foot (psf) which is the minimum roof live load specified by ANSI (Table 3 ANSI A58.1-1972). It is believed that this load is more appropriate than a live load of 4.67 psf (based on 1" thick ice) used by Northrup.
- c. Wind load Since it is conceivable that this system may be marketed in locations other than the Dallas-Ft. Worth area, the analysis for wind load was based on a wind speed of 110 miles per hour (mph) which is specified by ANSI for the coastal areas of the Gulf of Mexico, (Figure 2 ANSI A58.1-1972), rather than a wind speed of 70 mph used by Northrup. Using a wind speed of 110 mph, Exposure C which is specified by ANSI for flat open country, open flat coastal belts, and grasslands, and a height of less than 30 feet, a wind pressure of 46 psf (Table 6 ANSI 58.1-1972) was used in the analysis.

Two independent wind directions were considered in the

solutions--one in the plane of the frame and perpendicular to the plane of the collector, and the other in the plane of the frame and in the horizontal direction. The side wind loading is discussed separately.

The analyses indicate that the design of the various members of the supporting frame is adequate. The stresses in the members were computed using the loading combinations specified on p. 10 of ANSI. For each member the wind loading which resulted in the larger stress in that member was used in the combination. A summary of stresses in the members is given in Table 1. The allowable width to thickness ratios were computed using Section 2.3.1.1 of the Cold Form Specification, 1968 edition. The stresses are well below the allowable limits.

Side Wind Loads

The design of the wind bracing system for the horizontal side wind loads is based on a wind speed of 70 mph for heights less than 30 feet. Although the design is adequate for this wind speed, it will not be adequate for higher wind speeds encountered in other locations. If the system is to be used in other locations, the wind bracing needs to be increased by additional bracing in other side panels, increasing the size of the bracing, or a combination of both.

Deflections

The solutions for different loading conditions indicate that the deflections and rotations in the members and joints of the supporting structures are extremely small.

Connections

Examination of the forces in the south brace and the north column assemblies indicate that the design of the connections is adequate. Proper anchoring of the supporting system to the

foundation is necessary in order to avoid pull-out caused by the wind loading. In addition the assembly of connections should be properly carried out.

Collector Truss Assembly

The relatively small loads on each collector truss assembly result in extremely small stresses and deflections in the truss element which are well below the allowable.

Conclusion

Based on the analysis for different loading conditions and the examination of the structural design of the supporting system for the Northrup ML Series Collectors, Model NSC-01-0732, the following conclusions can be made:

1. The design of the supporting system is adequate for a live load of 16psf and a wind load based on a wind speed of 70 mph for heights of less than 30 feet above the ground. Since no seismic analysis has been carried out, the system should not be used in locations with a history of seismic activity.
2. With additional wind bracing, either by bracing more panels or using larger diameter rods, the design would be adequate for locations with a wind speed of up to 110 mph (such as the coastal belts), for heights of less than 30 feet above the ground and no seismic activity.
3. Proper tie-down of the supporting system to the foundation is necessary in order to avoid pull-out caused by the wind loading. No analysis of the foundation was carried out since it depends on the specific location where the system is to be installed.
4. The system can be certified for locations with no history of seismic activity and a wind speed of up to 70 mph and heights of less than 30 feet above the ground.

May 28, 1978

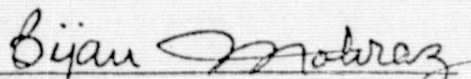

Bijan Mohraz, Ph.D., P.E.

Table 1 Summary of Stresses

Member	Axial ^(a) stress psi	Bending stress psi	Loading Combination ^(c)	w/t allowable	w/t actual
South brace	3374 C	433	D+L+W (horiz.)	93	85
Manifold Support ^(b)	2159 C	811	D+L+W (perp.)	116	81
Manifold Strut	1179 C	809	D+L+W (horiz.)	157	83
Inclined Strut	1513 T	861	D+L+W (perp.)		
North Column	3529 C	415	D+L+W (perp.)	91	79

(a) C = compression; T = tension

(b) Design of north manifold support governs

(c) D = Dead load; L = Live load; W = Wind load

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